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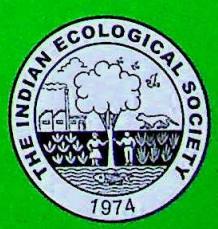

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Status of Poplar and Willow Culture in Himachal Pradesh

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Abstract: Poplars and willows are ecologically and economically important arboreal species for Himachal Himalayas. These are among a few tree species, which have been grown by the farmers especially in the cold arid region since ages for the tree based needs and by the foresters in their normal forestry programmes. Willow culture is restricted to upper hills especially inner Himalayas and that of poplar to outer Himalayas especially south of the Himalayan foot hills. Of late, poplars have attained a status of cash crop, which are grown in parts of some districts for sale to the wood based industry located within and outside the state. Back-end and front-end synergies in nursery-plantation-wood usage chain are now well established for poplar culture, whereas, similar synergies are lacking for willow culture. Willow has a specific use for making cricket bats for which there is no local wood processing industry. The paper gives an account of the existing practices in nursery and plantation management and marketing of wood for these species.

Key Words: Poplar, willow, status, culture, plantations, management

Himachal Pradesh, a Himalayan state, is natural home for some indigenous poplar and willow species which are closely associated with the socio-economical well being of locals who have been growing them since long for firewood, fodder and small timber especially in the cold arid region of the inner Himalayas and as a cash crop for sale to the wood based industry elsewhere. These trees have also been planted by the state forest department for ecological and forestry considerations. Besides some indigenous species, numerous other species and their clones were introduced from many other countries for their testing in the state. Many indigenously developed clones from the local tree improvement programmes have also been made available to the growers. Willows are the life line for tree based needs in cold desert region especially near timber line where other arboreal vegetation does not exist. *Salix fragilis* an arboreal bush or small tree, occurs near the timber line and has been reported to provide 69.5%, 29%, and 42% of the total fuelwood requirements of wood in Jahlma, Khoksar, and Hinsa villages of Lahaul valley, respectively (Rawat *et al.,* 2006). The species is a life line for tree based needs in many other similarly situated villages in the cold arid region. Poplar also has a long history of its culture in high hills but is now considered as a cash crop in locations where its growth and productivity is good and returns from its sale are more remunerative than those from the traditional agricultural crops. Growing poplar for this purpose is an extension of the activity from the Region of Intensive Poplar Culture (RIPC) comprising parts of adjoining states, viz., Punjab, Haryana, Uttrakhand and Uttar Pradesh states where the tree has been commercially grown for the last over three decades. This paper presents an account of the status of poplar and willow culture in the Himachal state and draws information from various reports, personal contacts and self experience having served almost all poplar and willow growing districts in the state including cold desert region of Kinnaur and Lahaul & Spiti districts during the peak of Dessert Development Project (DDP) implementation during 1980's when poplar and willows were planted in large number and also in the University of Horticulture and Forestry (UHF), Nauni, Solan.

Poplar and Willow Species

Populus ciliata (Himalayan poplar), is the only poplar species indigenous to the state. It is one of the associated species of deodar, fir/spruce, kail, and oak forests and is found in parts of Lahaul & Spiti, Kinnaur, Kullu, Mandi, Chamba, Kangra, Shimla, Solan and Sirmour districts in the state. Some monumental trees of *P. ciliata* are reported from cold desert region (Singh, 2000) and these appear to be planted long back. The species is not able to tolerate warm and hot weather conditions of plain areas and foothills, where if planted, maintains shrubby form for a couple of years and finally dies. Some authors consider *P. alba, P. balsamifera* and *P. suveolense* as indigenous poplars (Tewari, 1992; Khurana, 2007), while, others claim them as introduced ones (Naithani *et al.,* 2001). The fact that the natural stands of these species do not exist in the forests and their occurrence in isolated form around villages and gompas (Budhist temples) indicates that these were planted in this region long back. Historical accounts describe overlapping dynasties and rulers in Ladakh, Lahaul, Spiti, Kullu and Chamba princely states at different periods with frequent invasions from one territory to other (Negi, 1995).

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Introduction and occurrence of species like *P. alba*, and *P. balsamifera* and some others over these areas appear to have moved with migration of people with change in dynasties or otherwise. *P. alba* is adapted to cold arid conditions and exits in Lahaul & Spiti and Kinnaur districts. *P. balsamifera* has been reported to have affinity with Budhism as it is mostly located in the compounds of gompas. Encircling and flagging of these trees with sacred cloths by Budhists indicate their sacred value for this religion (Dhiman, 2010). *P. nigra* an introduced poplar from Afganistan has been regularly planted in some locations in Lahaul & Spiti and Kinnaur districts, and some trees could also be seen in some other districts especially in botanical gardens and research institutes. *P. nigra* was reported as the main dominant tree species among 142 plant species belonging to 49 families and 105 genera at 3000-5000 m elevation in Namgia village of Kinnaur District, H.P. (HFRIa). *P. deltoides* now occurs in all the districts of the state where it has been planted during the last three decades. UHF and state forest department have introduced many other species and cultivars for research and field trials which have been planted in the state and they along with some indigenously developed clones are also maintained in some germplasm plantations.

Willows are dominant tree genera in cold desert of Lahaul & Spiti and Kinnaur districts. The most important willow species found in the cold desert are *S. alba, S angustifolia, S. caesia, S. daphnoides, S. elegans, S. flabellaris, S. fragilis, S. hastate, S. oxyaxaropa, S. sclerophylla* and *S. tetrasperma* (Nautiyal, 1991). Natural stands of *S. fragilis* are found at number of locations near water courses and glacier sites in Lahaul and Spiti valleys. *S. alba* and *S. babylonica* are also seen in many other locations, the latter species is especially located in parks and botanical gardens in many parts of the state. *S. fragilis* is the only arboreal species which occurs in the upper Sipti valley beyond Hul village and in many locations of Lahaul valley especially those adjoining Spiti valley.

Plantations

Occurrence of some monumental trees of poplar and willow species viz., *P. balsamifera, P. ciliata, S. fragilis, S. viminalis, S. elegans,* etc. in and around gompas (Budhist temples) and habitations (Chauhan and Lakhanpal, 2000) indicates that plantation of these species have traditionally been invogue in this region since long. According to Singh (2000) planting of poplars and willows in this region has been taken up by the farmers since the advent of Moravian during mid 19th century. Agriculture crop production in this specific geo-ecological landscape is totally irrigation dependent for which water is drawn from natural streams. Most landowning families have been planting a few trees along the water channels feeding their fields or collectively on village common land, and their product and value are shared among the village families. Spiti valley in Lahaul & Spiti district represents complete arid conditions with absence of monsoon rains. Planting poplar is rare beyond Kaza, where *S. fragilis* along with *S. alba* are planted. In Spiti valley, below Kaza with its boundaries touching to Kinnaur district, *P. alba, P. deltoides, P. ciliata* along with *S. alba* and *S. tetrasperma* are main planted species. Lahaul valley represents slightly better conditions with rainfall ranging from 300-700 mm where *S. fragilis* is the most common tree planted but *S. vimanalis* and *S. insignis* are also grown (Singh, 1950). Among poplars, *P. nigra* and *P. alba* have been planted since long. Pooh division of Kinnaur district also represents semi-dried conditions where planting of poplars mainly *P. alba, P. ciliata, P. nigra* and *P. deltoides* is more common than willows.

P. ciliata is largely planted on forest land by the state forest department and to some extent by the research organizations in their research trials. The interest in poplar as a plantation species dates back to 1950's when planting of *P. ciliata* along with some introduced species were explored as a nurse crop for regeneration of fir and spruce forests in the state (Agarwal and Patil, 1956). *P. ciliata* with introduced *P. monilifera,* and *P. generosa* were tried and proved useful in regenerating fir and spruce in Kullu district but could not be replicated on a large scale. *P. deltoides,* is the main preferred species in poplar culture in the state. It finds favour among all growers viz., farmers, state forest department and research organizations for growing in locations from cold desert to Himalayan foot hills and valley areas. It is mainly planted in Balh valley of Sundar Nagar, Mandi district, Mand belt (Indora division) of Kangra district, lower areas of Una district, Nalagarh division of Solan district and Ponta valley of Sirmour district. The species was also introduced in the Spiti cold arid region during early 1980's and some of its plantations are better grown than many other plantations of other species. The main cultivars of poplar commercially grown in the state are the same, which are grown in the RIPC. These include G48, Udai, WSL 22, WSL 39, etc. with some last year released clones specifically WIMCO 81, WIMCO 83 and WIMCO 110 also now finding favour among the growers in the plains. University of Horticulture and Forestry (UHF) has developed and recommended some clones of poplars and willows for growing in the state (Table 1).

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Table 1. University of Horticulture and Forestry (UHF) recommended clones of poplars and willows for the Himachal state

S. No.	Species	Clone	Zone (m. amsl)
1	*Populus ciliata* and hybrids	UFC-1000, UFC-1900, UFC-2200, UFC-010, UFC-6403, IL-3B	>1500
		UCM-3287, UCM-3220, UCM-3296, UCM-2801, UCM-113	1000-1500
2	*P. deltoides* and hybrids	UD-5503, UD-6502, UD-10007, UD-3210, UD-3296, UD-8800 and Hybrids Solan-1, Hyb-U	1000-1500
		UD-0102, UD-0700, UD-6500, UD-4400, UD-7007, UD-8800, IC, 200/86, 52/86 and P1/92	300-1000
		UD-5501, UD-5512, UD-6501, UD-6502, UD-1007, UD-63N, G-3, D-121 and S7C16	<300
3	*Salix alba* cv. *coreulea*	006/05, 006/06 and KW	
	S. alba	SI-63-007, SI-64-017 and SI-62-096	
	S. matsudana	SE-63-016	
	S. matsudana x S. alba	799, NZ 1002, PN 733, NZ 795	
	S. matsudana X S. arbutifoillia	NZ 795	

(Source: www.yspuniversity.as.in; Singh *et al.*, 2014)

HFRI has established field trials with number of species viz., *Salix fragilis*, *S. vitellina*, *S. matsudhana*, *S. babylonica*, *S. alba* and *S. corrulea* introduced from Jammu & Kashmir and also with UHF clones, viz. UWA-1, UWA-2, UWE-1; UWM-1, UWM-2, UWM-3, UWU-1, UWU-2, UWK, UWHY-1, UWHY-2, and WO2-4 to screen suitable productive and resistance clones (HFRIb). Five clones i.e., J-799, NZ-1140, 131/25, SI-63-007 and PN-731 out of 200 introduced ones have been shortlisted after five years trial based on tree height, dbh growth and clear bole for lower and mid-hills of Himachal Pradesh (Sharma *et al.*, 2011). Individual tree growers and state forest departments are the main stack-holders in poplar plantation programmes. Some poplar is also planted by the research organisations like state agricultural universities especially UHF, Krishi Vishva Vidhyalaya Palampur, Kangra and Himalayan Forest Research Institute (ICFRE), Shimla on their campuses including research centres. State Forest Department has been planting poplars and willows on forest land since long and the data on species-wise planting is available from 1950's (http://himachal.gov.in). Out of a total planted area of 10,26,776 ha under different schemes till date (w.e.f. 1950 to 2009-10), poplar and willow plantations cover 14,958 ha and 10,407 ha, respectively. Poplar therefore represents 1.46% and willow 1.01% of the total plantations made in the state so far. Many of the species planted in the state are slow growing conifers and broadleaved species, the share of poplar and willow planted area is therefore likely to be very low as most of the earlier planted poplars and willows could have lived their physical age. Both species are also highly sensitive to moisture status of planted sites, the initial and final survivals of planted poplars and willows likely to be lower than the hardy conifers and some broad leaved trees.

The state plants around 2 crore plants per year, out of which, poplar and willow constitute 0.58% and 0.57%, respectively. During the last two years i.e., 2008-9 and 2009-10, an average of 1,97,04,735 plants were planted annually. There were 21 plantation schemes, out of which poplars and willows were planted in 14 schemes. Some species specific or programme specific schemes like bamboo mission, regeneration of chilgoza forests, TFC, SWAN, CAT, etc. did not have poplar and willow plantations (Table 2). Poplar plantations under CAT plan has maximum plantation of poplars (28.40%) followed by Backward area sub plan (19.37%), Improvement of tree cover (12.93%), Plantation under MHWD project (9.08%), Soil conservation (7.61%), Enrichment planting (5.83%), Compensatory plantations (5.31%) and others indicate that poplar is planted for multiple purposes. Similarly for willows, maximum plantation was in improvement of tree cover (25.64%) followed by soil conservation (22.70 %), pasture development (14.76%) and scrub development (11.14%) schemes and this species has also been planted for multiple purposes.

Circle-wise data of poplar and willow planting during these two years (Table 3) further confirms that both poplar and willow have almost average equal planting figures. However, poplar is planted over greater area than willow and the latter is mainly planted on high altitude locations. Lahaul Forest Division is attached to Kullu Circle and Spiti and Kinnaur forest divisions to Rampur Circle where planting of both poplars and willows is collectively more than many other circles. Bilaspur and Hamirpur forest circles located in

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Table 2. Average annual planting of poplar and willow under different schemes during 2008-09 and 2009-10.

S. No.	Plantation scheme	Poplars		Willows	
		Total planted (No.)	Share of scheme (%)	Total planted (No.)	Share of scheme (%)
1.	Pasture development	5060	4.57	16625	14.76
2.	Improvement of tree cover	14312	12.93	28888	25.64
3.	Enrichment planting	6450	5.83	6075	5.39
4.	Reforestation of scrub areas	3267	2.95	12547.5	11.14
5.	Sanjhi van yojna	1925	1.74	5674.5	5.04
6.	Soil conservation	8425	7.61	25572.5	22.70
7.	Backward area sub plan	21441	19.37	5037	4.47
8.	FDA samridhi yojna	620	0.56		
9.	Compensatory plantations	5883	5.31	3025	2.68
10.	Macro management (RVP)	1835	1.66	530	0.47
11.	Plantation under CAT plan	31427	28.40	4965	4.41
12.	TFC			400	0.36
13.	Improvement of WL areas			1375	1.22
14.	Plantation under MHWD project	10050	9.08	1950	1.73
	Total	110703	100.00	112664	100.00

(Source: http://himachal.gov.in)

the lower Himachal have some poplar plantations by the private growers though government figures do not show any planting in those areas. The plantation figures further confirm planting of both species under wildlife and watershed programmes.

Poplars and willows were the main tree species planted in a centrally sponsored programme -Desert Development Project (DDP), which was launched for Spiti division of Lahaul and Spiti district in 1978 and for Pooh division of Kinnaur district in 1982 with special emphasis on rehabilitation of cold desert. Under this programme, 16,36,735 plants were planted over 830 ha (Negi *et al.*, 1996). *S. fragilis* is the main species planted in Spiti DDP especially over the greater part beyond Kaza. The plantations of *S. fragilis* in lower elevations sustain but is not very productive in comparison to other willow and poplar species regularly planted there. Similarly, planting of many other willow and poplar species in higher elevation locations could not survive due to extreme cold conditions.

Two regional centers of UHF viz., RHRS Jachh and HRRS, Dhaulakuan and its main campus at Solan have been producing poplar saplings for own use and to supply them to tree growers of the locality since mid 1990's. According to Chauhan (2012), Jachh and Dhaulakuan centers have produced and supplied 89,207 and 1,63,305 saplings respectively till 2012. The annual supply is worked

Table 3. Average annual planting of poplars and willows in different forest circles during 2008-09 and 2009-10.

S. No.	Forest circle	Poplar planting during (No.)			Willow planting during (No.)		
		2008-9	2009-10	Average	2008	2009	Average
1.	Kullu	63391	27775	45583	68667	15058	41863
2.	Shimla	5912	15555	10734	36908	12900	24904
3.	Rampur	22058	23306	22382	5575	3428	4502
4.	Chamba	300	8969	4635	13460	32400	22930
5.	Dharamsala	1050	640	845			
6.	Nahan	12900	300	6600			
7.	Wildlife Shimla	12650	5600	9125	15125	9082	10729
8.	Wildlife Dharamsala		300	150		500	250
9.	Wildlife Shamshi		600	300	6450	1875	4162
10.	MHWD Solan	20100		10050	1250	2650	1950
	Total	138361	83045	110703	147435	77893	112664

(Source: http://himachal.gov.in)

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out to be 8,600 saplings from Dhaulakuan and 5,500 saplings per year from Jachh. The university had a saleable stock of around 800 fully grown poplar trees that was put to auction during 2011. Himalayan Forest Research Institute is also raising poplar and willow nurseries which have been established in different locations including cold desert region. Some poplar has also been planted by the Public Welfare Department (PWD) along road side especially along national highway around Solan town.

A major share of the planting stock planted by the growers in the plain and in some valley areas is supplied by the private nursery growers from the adjoining poplar growing locations like Hoshiarpur, Ropar (Rupnagar), and Pathankot districts in Punjab and Yamunanagar and Panchkula districts in Haryana. Poplar and willow wood does not find better market within the state. There are only 3-4 plywood factories in the lower Himachal, which use poplar wood for making panel products. The major part of poplar wood harvested in the state is traded at Yamunanagr wood market in Haryana and Hoshiarpur in Punjab. Both these locations are leading centers for poplar sapling production as well. Wood traders who transport wood from different locations of the state also carry saplings from these locations and supply them to the growers during the planting season. Many of good growers especially near the RIPC also directly procure planting stock from the branded nurseries located in the RIPC. Some private nurseries have also come up in Indora belt of Kangra, Plain areas of Una district, Nalagarh area of Solan district, Paonta valley of Sirmour district and Balh valley in Mandi district to meet the increasing demand of the growers. It is inferred that around 6 lakhs poplar saplings were planted in the state during 2012 planting season and the major share of the planting stock was supplied from the adjoining RIPC.

Plantation Management

Willows and poplars have been planted since long back by the local inhabitants of Lahaul and Spiti using their traditional knowledge (Singh, 1950). Planting is carried out in March-April on melting of snow with a piece of branch with the last year growth-commonly called as a set. Sets of 15-20 feet length with fresh bark are made from the actively growing coppice shoots. Set made from side branches have poor apical dominance and are reported not to perform good. The practice has been to plant a bunch of 4-5 sets together to ensure that at-least a couple of them survive and also to avoid animal damage to at-least some inner sets. Sets are planted 2-3 feet deep in crow bar made holes and carefully firmed up during planting. Sets near villages are normally covered with some old clothes, jute ropes, prickly shrubs like *Caragana* and *Hippophae* to avoid stripping of the stem bark by animals. Much has not changed in the planting technique of willows and poplars in the cold arid region except for the length of the planting set has now been reduced to around three feet on increasing their demand under various plantation programmes. Government institutions taking up large scale plantations especially under DDP created market for sale of sets and as a source of earning for the locals from own trees or from village common tree groves. Further the plantation areas was extended to the newly developed command areas of irrigation network and the success of plantations was closely associated with the success of irrigation system developed for this purpose. The plantation areas are protected by stone wall fencing, which is more effective than barbed wire fencing but very costly. The scope of growing nursery saplings in the upper parts of cold desert is limited due to extreme cold conditions, limited growing period, poor soil-site conditions, poor water availability, etc. It generally takes two growing season to attain a plantable size of around one meter length of the nursery plant and therefore the practice of planting sets is common in upper part of Spiti and Lahaul valleys. Polybag raised plants of poplars and willows were also used for making field plantations during offseason, yet the method proved costly and difficult in transportation and planting operations. In other areas, nursery grown saplings commonly called as ETP (Entire Trans-plants) are used for field planting. Poplar nurseries in the lower region are established with stem cuttings made from last year ETPs and plants grow to 3-4 m in one year period. ETPs on uprooting are conditioned in fresh water from 1-2 days before planting in augor made holes. Fields are immediately irrigated on field planting for better survival and early growth.

Both poplars and willows coppice well and these are worked under pollarding system for yielding firewood, fodder and small timber in the cold arid region. The tree trunk is cut at a height and managed for regular harvest of coppice shoots after every 2-3 years. Poplar is generally harvested for poles and timber, though some examples of pollarding are also available. Some examples of coppicing trees are also available (Sharma *et al.,* 2006). In lower Himachal, poplar is harvested and replanted as per the practice followed in the RIPC. *P. alba* is heavily lopped for firewood and fodder and also to meet the domestic needs for construction and agriculture implements. Major part of poplar and some part of willow are grown in agroforestry. Both traditional and commercial forms of poplar based agroforestry are available in the state. The trees have been integrated with agriculture crops under rainfed (Chauhan and Dhiman, 2003), and irrigated crop production systems

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(Singh and Negi, 1996), pastures (Chauhan and Dey, 1999), medicinal plants (Thakur and Dutt, 2007) and horticultural orchards (Pathak and Singh, 2000). Kumari *et al.* (2008) reported traditional agri-silviculture systems in Kinnaur district where agricultural crops are integrated with poplar are kidney beans (rajmash), peas, capsicum (bell pepper), ogla, fafra, potato, cauliflower and barley in the villages of Sangla, Kupa, Pooh, Nako, Rakcham with a total of 11.65 bighas under this system in comparison to 42.2 bighas of agri-horticulture system, which is the dominant form of traditional form of agroforestry in this part. Poplar is integrated with normal agriculture crops like wheat, sugarcane, maize, potatoes and others in the lower parts of the state.

Many villages maintain and manage their groves of willows and poplars for firewood, fodder and timber. There is an age old practice of participatory management of village common wood lots including that of willows and poplars in the Inner Himalayas (Dhiman, 2002; Gupta and Singh, 2003). This practice is an extension of the overall management of common property resources (including natural resources like forests and water) in which villagers collectively take decision on management, protection, harvest and sharing of their produce. One such case, among many in the region, is quoted from the Lossar village situated at 13,500 feet altitude is 68 km away from Kaza on Kaza-Kullu state highway and is the last village on this route near the timber line. Coppice shoots of willows (mainly that of *S. fragilis*) are harvested for small timber, firewood, fodder and for sale as sets for making new plantations. The management of the willow forests and harvest of coppice shoots is decided by a 3 member committee headed by Nambardar (village chief) and 2 other members of the villager who are selected from each house by rotation. The area is divided for harvesting and each year a different area is selected and the remaining is allowed to grow. All willow shoots are harvested from stumps during April by employing one or two members from each family. The harvested shoots are made into 1m long sets, which are sold to different agencies for field planting. The lops and tops of these branches are equally distributed among the villagers for use as firewood. During the DDP activities in 1980's around 10,000 sets were annually supplied to the project for planting activity. Every amount of sale of willow shoots and from other collective work is received through Nambardar and is equally distributed among the village families. Besides willow sets, villagers also work collectively in making plantations, their irrigating, watch and ward and in soil conservation works to protect these plantations and other land resources. The committee decides the number of persons to be engaged from each family for planting, irrigation, making stone wall fencing, etc. Persons for watch and ward work are selected by drawing the lots. Each family gets a job for 3-4 months in already made plantations. If any village member violates the instructions of the committee, he is fined with money and other locally available articles. Offenders are asked to undertake an oath in front of the committee for not violating the instructions of the committee. It is believed in the area that taking wrong oath results in some bad omen and therefore people not try to engage in breaking the verbal instructions, which are duly followed. Some poplar is also being planted for shade in tea gardens in Kangra district.

Growth and Productivity

The growth and yield studies of poplars and willows are available from some locations within the state. Poplars are planted under varied soil-site conditions viz., forest land, farmland integrated with crops, pastures and around orchards. Available figures indicate that poplar growth on many locations is subnormal when compared with that grown in the RIPC. Establishment, growth and productivity of poplars and willows is severely affected by the limited growth period, low temperature, inadequate cultural inputs, poor soil and site conditions, unfavourable weather conditions (especially prolonged dry spells), and type of species and cultivars used in plantations. Planting success is also reported to be affected by the quality of planting stock including sets, moisture availability during planting and thereafter, and depth of planting etc (Joshi and Nayital, 2006). The entire poplar and willow plantations in the cold desert region are carried out with assured irrigation, any disruption in the irrigation system results in their failure. *P. deltoides* is reported to be more sensitive to prolonged droughts than indigenous broadleaved species like *Grewia optiva, Morus alba* and *Dalbergia sissoo* studied under mid Himalayan conditions (Thakur and Sood, 2005). *P. deltoides* is faster grown than other available species. Thakur and Chauhan (2008) reported better growth of *P. deltoides* among the six species tried *(Alnus nitida, Salix tetrasperma, Eucalyptus tereticornis, Robinia pseudoacacia, Pinus roxburghii* and *Dalbergia sissoo)* on the riverian tract of Kullu, Himachal Pradesh. Irregular increase and decrease in current annual increment in *P. deltoides* is mainly attributed to the flooding of area (Chauhan *et al.,* 2007). Chauhan and Dey (1999) reported diameter growth of 12 years old *P. deltoides* between the range of 5-25 cm diameter with average biomass of 34.2 t/ha. In Bajaura Kullu, Clone I-C with a maximum ring width of 12.210 mm showed superiority over rest of the clones. The clones like I-C, G-48, D-121 and C-181 showed

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high growth rate and are adaptable to different environmental conditions.

The rotation of poplar is longer in hills than in plains in the state. The average productivity of poplar plantations in the lower parts of the state is around 15-20 cum ha^{-1} $year^{-1}$ which is better than that in upper regions of the state but slightly lower than the one recorded in the RIPC. In the middle and upper hills, the yield is much below this. An inventory of the trees grown in the UHF campus, Nauni, Solan and placed for auction during 2011-12 (Table 4) is an indicator of the poplar productivity in mid hills. Most of these plantations were reportedly of over 20 years age. Poplar grows good in some specific nitches near natural nallahs (seasonal rivulets) and the large portion of the university campus is not very suitable for poplar culture because of rainfed conditions and poor soil site conditions. Planting of poplar on this land is part of research trials that university conducts with poplars. The inventory of harvestable trees indicate a large number of 34 dead and dried trees. The visibly healthy trees are also expected to have high degree of internal damage like heartwood rot or termite attack, which is common in poplar grown for such a long rotation. A plantation of 520 number of six years old trees harvested in Bilaspur district a few years back out of which around 80 per cent were hollow inside as these were grown on rainfed conditions having high degree of termite attacked.

In DDP, plantation costs are stated to be very high particularly if they are calculated on the final survival of plants. According to evaluation of the DDP programme, Negi *et al.* (1996) reported the cost incurred on each plant was Rs. 38.7, which did not consider the indirect cost spent on developing irrigation facilities for these plantations. It was calculated on surviving plants during the evaluation of the project in 1993 when it was discovered that out of 16,36,735 only 54% plants (8,84,307 number) survived.

Willows are lopped for firewood and fodder at intervals of 2-3 years in cold desert region. The trees attain a height of around 5 m in around 10 years (Singh, 1950). Tree size and their location (nearness to water course) affect shoot production in pollarded trees. Higher girth trees produce more shoots compared to low girth trees and the figure may vary from around 218 shoots in >90 cm to just 28 shoots in 1-30 cm girth trees (Rawat *et al.*, 2009). It is also reported that shoot number per tree and their thickness is also similarly influenced by tree girth. Mortality of shoots due to self pruning is more in small trees than that in old trees. Maximum height of 19.33m was claimed for clone J-799, 16.5cm diameter for NZ-1140 and 131/25 and bole straightness for J-795 (Sharma *et al.*, 2011).

Marketing of Produce

Himachal was the first north Indian state to issue notification for taking willows and poplars out of transit and felling regulations during 1970's. Despite high demand for its wood for cricket bats, willows have yet to be picked up for commercial farming in the state. Poplar wood is now used in a couple of plywood factories, which came up in Kangra, Solan and Sirmur Districts. Major market for trading poplar wood harvested from the state still remains in the adjoining states of Punjab and Haryana. The main wood trading centers for poplar wood grown are Pathankot and Hoshiarpur in the state of Punjab and Yamunanagar in Haryana. Poplar wood is directly sold to contractors at negotiated price who then supply it to the main contractors, commission agents or directly to the factories. A few good poplar growers near to these markets also directly supply wood to the factories.

Major research on both indigenous and introduced poplars and willows in the state has been carried out by UHF and Himalayan Forest Research Institute of ICFRE (including its erstwhile Conifer Research Centre, Shimla). Some research support on poplars has also been from the State Forest department, Agriculture University Palampur, Kangra and private sector company-WIMCO. The major focus of research on poplars and willows has been on tree improvement, nursery and plantation techniques, plant protection, growth and yield studies and tree-crop interaction

Table 4. Inventory of saleable poplar trees in the UHF main campus

S. No.	Tree diameter (cm)		Visibly healthy trees (No.)	Damaged and dried trees (No.)	Total trees (No.)
	Class	Mid value			
1	10-20	15	24	2	26
2	20-30	25	567	27	594
3	30-40	35	145	3	148
4	40-50	45	28	-	28
5	50-60	55	4	-	4
6	60-70	65	2	2	4
	Total	765	34	799	

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involving *P. ciliata, P. deltoides, P. alba, S. fargilis, S. alba* and with some other introduced species and cultivars. New developed cultivars by the private sector WIMCO, which are widely grown in the RIPC have also been procured by the state forest department, universities and farmers for research and field plantations. There was a proposal of initiating refinance scheme for poplar culture in the state on the same line that was implemented in the RIPC. A large number of planting stock was procured from the company and planted in Balh valley in Sundarnagar, Mandi at that stage.

Poplar is planted in the state for three main purposes viz., domestic tree based needs environmental and forestry purposes and as a cash crop. With expanding willow and poplar culture and possibly with climate change, challenges for their sustenance are also increasing. Willows in Lahaul & Spiti district are now highly threatened by pests and diseases infestation, which has fast invaded new plantations and locations. It is reported to be infected with *Cytospora chrysosperma* and giant willow aphid (pest). Reports indicate mortality upto 70% in some villages (Rawat *et al.*, 2009). Poplar is now routinely grown as a cash crop in number of locations in the state. Alike RIPC, poplar has now well established backward and forward linkages for planting stock procurement and wood disposal within and outside state. Willow is now being recommended for field plantations but has yet to pick up the momentum. There is good demand for its wood in cricket bat industry. This tree also needs support of backward and forward linkages to make its culture self sustaining similar to poplar culture.

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Indian Journal of Ecology

The Ecological Aspects of the Production of Electricity in Power Generator Systems

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Abstract. This paper presents problems related to the use of municipal landfill gas as a fuel for engines powering electric generators. The authors focus mainly on the energy-related and ecological aspects. In the first part of the paper the authors briefly analyzed the legal regulations related to the use of alternative sources of energy, municipal landfill gas in particular. In addition, analysis shows that due to a large amount of accumulated waste we should expect a bigger global production of municipal landfill gas in the nearest future. The paper also presents the authors' own results of emission tests performed on a power generator fuelled with landfill gas and these results were compared with the emissions generated during the production of electricity from coal and lignite and from a diesel engine operating in the power generating system. The ecological evaluation of the use of municipal landfill gas in combustion engines has been complemented with the evaluation of the ecological benefits of the tested power-generating unit. This evaluation has been carried out based on the calculation scheme by the United States Environmental Protection Agency (EPA).

Key Words: Biogas, combustion engine, renewable energy, emission measurement

The last century was characterized by rapid technological advancement accompanied by a rapid development of the industry. The spur for this development was the improvement of quality of life. Due to pollution there are more human and animal diseases, forests are dying, the soil is becoming barren and the climate is getting warmer.

Today the priority is a sustainable development seen as a process that unconditionally joins the present needs with the needs of the future generations. Sustainable development could also be interpreted as a supra generational agreement that will secure fair condition of the environment for future generations. In light of this peculiarly defined objective comes a question of how to live up to this expectation. For many years we have seen actions aiming at environment protection in industry and transport. More and more stringent ecological requirements have been implemented. In this aspect energy production is one of the main areas of interest where on the one hand alternative sources of energy are being sought and on the other hand work continues on the improvement and perfection of conventional energy production. Unfortunately, the development of industry is equivalent with a higher demand for fossil fuels – coal, lignite, crude oil and natural gas. An extensive exploitation of the fossil fuels and the accompanying environmental pollution have forced humanity to seek new sources of energy that constitute a lower environmental nuisance. In these sources need is to include energy from municipal landfill gas i.e. generated as a result of the fermentation of municipal waste. Aside from municipal waste a source of this gas is also animal and plant generated biomass. Yet another source is biogas generated in sewage farms. It is commonly accepted that biogas (including landfill gas) can play an important role in reaching the target, Europe's 202020 i.e., obtaining 20% of energy from alternative sources by the year 2020.

The act that has the greatest impact on the future use of electricity as generated from renewable sources is the Directive of the European Parliament and European Council 2009/28/WE dated April 23rd, 2009 on promoting the use of renewable energy. Based on this directive, objectives have been set that Poland must achieve with regards to renewable energy use in the future years. This directive forces the implementation of a policy requiring the use of renewable energy in electricity production, transport, heating and refrigeration. The strategy developed for Poland was adopted by the Cabinet of Ministers on 7 December 2009. It provides for a gradual increase in the share of renewable energy use for the three main energy-consuming sectors: heat engineering, refrigeration, energy production and transport (Fig. 1). It is characteristic that in the analyzed period (until 2019) the highest increase in the energy share from renewable sources falls in the electricity production sector- this share is to grow by 6.59%, while for heat engineering and refrigeration by 3.72% and transport by 2.83% (Anonymous, 2009, 2011a).

All actions of the Polish Energy Policy aimed at fulfilling the Directive 2009/28/WE are positive. Development based

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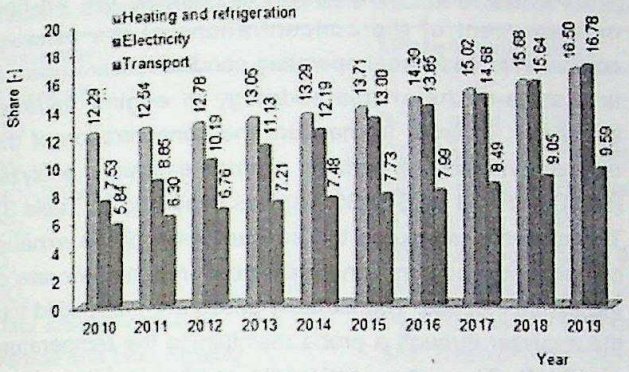

Fig.1. The assumed level of usage of renewable energy sources in Poland (Anonymous, 2011a)

on renewable sources is necessary even though in many cases the costs of production of such energy are higher than production based on traditional fuels. A national policy in this matter should contribute to a rapid development and use of renewable energy.

The experts' general opinion is that the greatest potential for development in Poland are sources utilizing biomass, biogas and wind energy. Sources utilizing solar energy can play important roles chiefly in heat production, which is reasonable from an economic point of view. In recent years in Poland there has been a development of power stations generating energy from landfill gas. The efficiency of these power stations is growing systematically (Fig. 2).

Furthermore, the European Commission and international scientific centers pin their hopes to this source of energy (ECF, 2010, Evans, 2011, O'Connor, 2010, Shukla, Murty, 2011). According to the data of the EPA (Environmental Protection Agency) the amount of acquired methane from waste disposal sites will be growing until 2020 (Fig. 3). From these forecasts it results that within the next decade the production of methane from the disposal sites in Poland will remain on a constant level and will

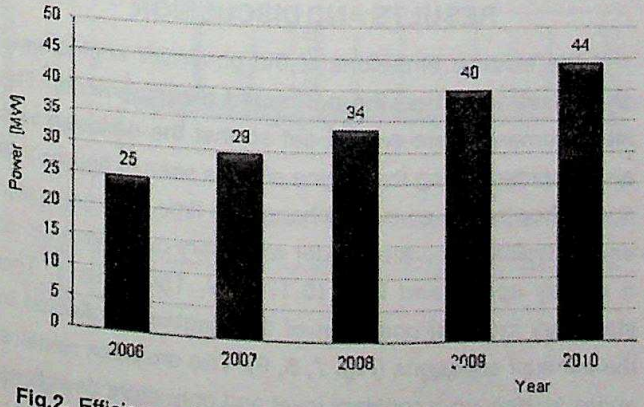

Fig.2. Efficiency of power stations generating electricity from landfill gas in Poland (Anonymous, 2011b)

amount to approximately 2% (which constitutes an equivalent of approximately 17 $MtCO_2eq$) of the world methane yield from this source (EPA, 2011).

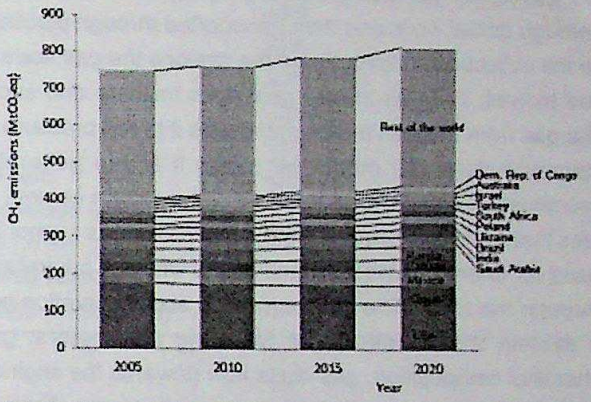

Fig.3. Forecast of methane emissions from municipal solid waste by country in 2005–2020 (EPA, 2011)

A good example of energy potential accumulated in waste disposal sites is the United States. Waste disposal sites are the third anthropogenic source of methane emission in the United States and in 2009 methane generated in these disposal sites constituted 17% (6 840 000 tons) of the total methane emission in the United States. It is estimated that from one million tons of waste, 12 233 m^3 (8 685 tons) of methane can be obtained daily (EPA, 2011). What is significant is that the most frequently used method of electricity production from landfill gas utilizes a piston combustion engine (Fig. 4). The above example confirms the potential of waste disposal sites as a source of cheap alternative energy. Assuming that all the waste disposal sites generate methane, it is worth our while to use this gas for energy generation rather than letting it escape into the atmosphere. It is thus one of the best and cheapest ways to reduce the human environmental impact.

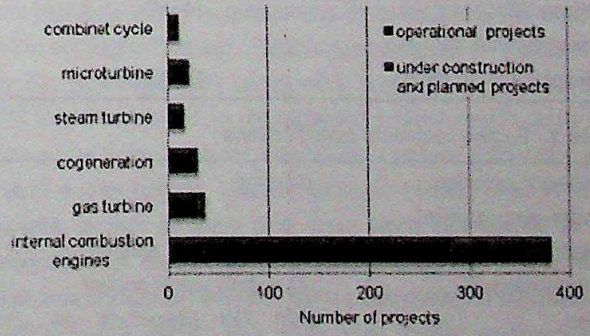

Fig. 4. Technologies used for production of electricity from landfill gas (Dielmant, 2011)

MATERIAL AND METHODS

The object of the investigations was a landfill gas fueled combustion engine power generator with the power output of 0.2 kW. The exhaust emission tests were performed on

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this engine. The emission of carbon dioxide, carbon monoxide, hydrocarbons, nitric oxides and sulfur dioxide were determined. In the particular case of the tested generator, the gas is acquired directly from the disposal site through drilled wells and then transported through pipelines to the collecting stations. From the stations the gas flows to the blower. The gas blower generates vacuum and sucks the gas from the well then compresses it to the pressure of approximately 100 mbar and sends it to the generator (combustion engine) or a torch. At the methane content of less than 30% and oxygen more than 3% the gas cannot be used for energy conversion and that is why it is neutralized through the torch. The gas acquisition and preparation has a system that monitors the following parameters: gas chemical composition, gas mass flow (towards the engine), combustion engine and electric generator operating parameters and the parameters of the generated electric current. The view of the landfill gas-feeding pipeline and the tested engine with the generator have been presented in figure 5. Table 1 shows the landfill gas composition during the tests and table 2 the engine technical specifications.

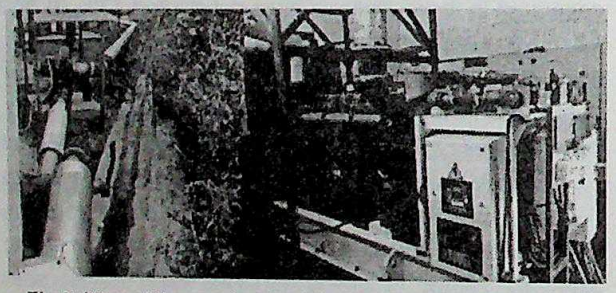

Fig.5. View of the gas feeding pipeline and the engine with a generator

Table 1. Gas composition during the tests

Compound	Per cent
Methane (CH_4)	45.5
Carbon dioxide (CO_2)	47
Hydrogen sulfide (H_2S)	0.043

Table 2. Engine technical specifications

Number of cylinder/ cylinder arrangement	6/in-line
Cycle/combustion system	4-stroke/spark ignition
Displacement	22.9 dm³, water-cooled
Power	200 kW (depends on gas content)
Compression ratio	9.5
Gas/ignition system	Air/fuel mixer with zero pressure regulator and mixture adjustment screw/individual cylinder ignition coils
Induction system	Turbocharger

During the tests methods based on on-line measurement of the concentrations of the exhaust components under real operating conditions were used. It is a state-of-the-art methodology in engine exhaust emissions. In order to measure the concentration of the exhaust emissions a portable exhaust emissions analyzer (SEMTECH DS by SENSORS) was used (Fig. 6, Table 3). The analyzer measures the concentration of the exhaust components and simultaneously measures the flow rate of the exhaust gases. The exhaust gases are introduced into the analyzer through a probe maintaining the temperature of 191°C. Then the particulate matter is filtered out (compression ignition engines) and the exhaust is directed to the flame-ionizing detector (FID) where hydrocarbons (HC) concentration is measured. The exhaust gases are then cooled down to the temperature of 4°C and the measurement of the concentration of nitric oxides (NO_x, NDUV – non-dispersive ultraviolet analyzer), carbon oxide and carbon dioxide (CO, CO_2, NDIR – non-dispersive infrared analyzer) and O_2 follows in the listed order. It is possible to add data sent directly from the vehicle diagnostic system to the central unit of the analyzer and to use the GPS signal. The GPS signal is mainly used in road vehicle tests.

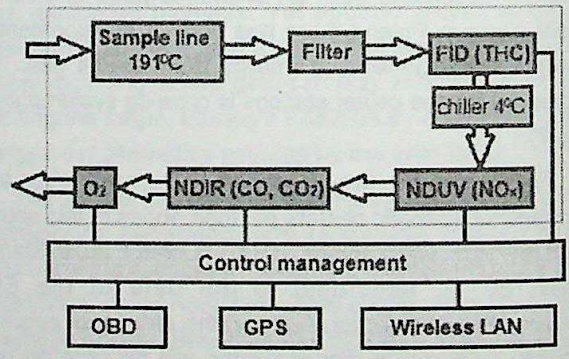

Fig.6. Diagram of a portable exhaust emissions analyzer SEMTECH DS; exhaust gas flow channels (arrow) and electrical connections circled (blue line)

RESULTS AND DISCUSSION

The exhaust emissions of the generator engine were determined based on the performed measurements. The measurements were carried out so that the emission was also recorded during the engine start as seen in figures 7, 8 and 9 showing the emission changes in time. The generator engine typically operates under stationary conditions i.e. at a steady speed and load (0,17 MW, 1500 min^{-1}). The stationary mode of operation of this engine is reflected in the exhaust emissions (Fig. 7, 8, 9). The emission remains approximately on a constant level and only slight deviations from this level are visible (the largest for hydrocarbons).

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Table 3. Characteristics of a portable exhaust emissions analyzer SEMTECH DS

Parameter	Measurement method	Accuracy
Emissions		
CO	NDIR, range 0–8%	±3%
HC	FID, range 0–10.000 ppm	±2%
NO_x=NO+NO_2	NDUV, range 0–2500 ppm	±3%
CO_2	NDIR, range 0–20%	±3%
O_2	Electrochemical, range 0–25%	±1%
SO_2	Electrochemical, range 0–1000 ppm	±3%
Data storage capacity	Over 10 hours at 1 Hz data acquisition rate	
Vehicle interface capacity	SAE J1850 (PWM), SAE J1979 (VPW)	
	ISO 14230 (KWP-2000)ISO 15765 (CAN),	
	ISO 11898 (CAN)SAE J1587, SAE J1939 (CAN)	

The stationary conditions of the generator engine operation is one of the main advantages of this system as it is commonly known that dynamic states (changes in engine speed and load) have the greatest negative impact on the exhaust emissions. This is an argument supporting the use of landfill gas for the fueling of generator engines rather than road vehicles that operate under dynamic conditions.

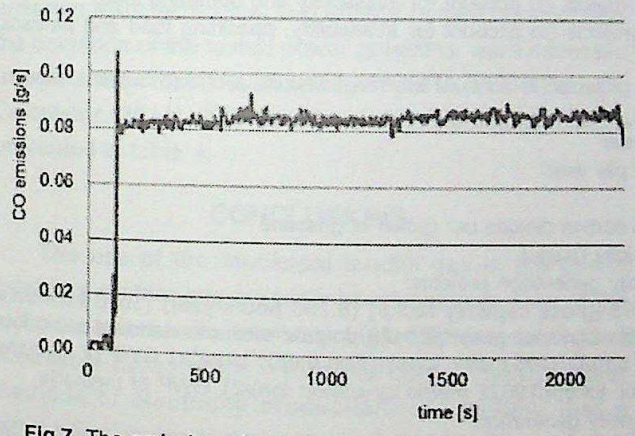

Fig.7. The emission of carbon monoxide from a landfill gas fueled engine during the tests

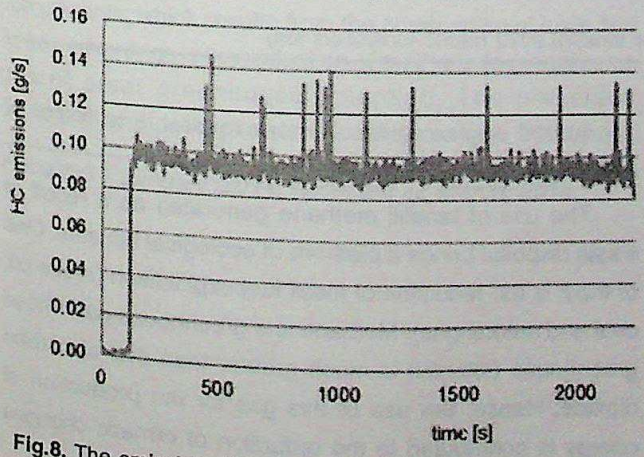

Fig.8. The emission of hydrocarbons from a landfill gas fueled engine during the tests

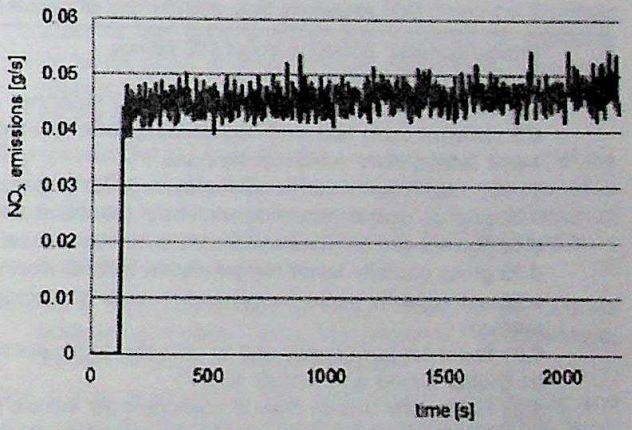

Fig.9. The emission of nitric oxides from a landfill gas fueled engine during the tests

The emissions from the generator engine fueled with landfill gas were compared with the emissions generated in the production of electricity from other sources (Fig. 10). In Poland the greatest share of the production of electricity is held by power stations utilizing coal or lignite as the main fuel which is why it is purposeful to compare these sources in the ecological aspect. For this purpose, the data published by the electricity manufacturers was used (Anonymous, 2011b). Moreover, a comparison was made with the emissions from a diesel engine of a power generator with 10kW power output. The emission of carbon dioxide, nitric oxides, sulfur dioxide and dust were compared in the production of electricity from coal and lignite. The emitted dust was compared with the particulate matter (PM) emission from diesel engines. The particulate matter emission from spark ignition engines is negligible and hence, it was not included for the engine fueled with landfill gas. Based on the presented results we can observe that the production of electricity with the use of engine power generators fueled with landfill gas is more advantageous in terms of the emission of sulfur dioxide and particulate matter/dust when

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Table 4. The results of the calculations of ecological and energy related benefits that result from the production of electricity from municipal landfill gas

1.	Direct equivalent emissions reduced (reduction of methane emitted directly from landfills):
	• 0.0065 $MMTCO_2eq/yr$ (million tons of carbon dioxide equivalent per year
	• 339 tons CH_4/yr (tons of methane per year)
	• Equivalent to any one of the following annual benefits:
	  • Annual greenhouse gas emissions from 1234 passenger vehicles
	  • Carbon sequestered annually by 557 ha acres pine or fir forests
	  • CO2 emissions from burning 34 railcars' worth of coal
	  • CO2 emissions from 2747164 dm3 of gasoline consumed

2.	Avoided equivalent emissions reduced (offset of carbon dioxide from avoiding the use of fossil fuels):
	• 0.0008 $MMTCO_2eq/yr$ (million tons of carbon dioxide equivalent per year)
	• 835 tons CO_2/yr (tons of carbon dioxide per year)
	• Equivalent to any one of the following annual benefits:
	  • Annual greenhouse gas emissions from 145 passenger vehicles
	  • Carbon sequestered annually by 66 ha pine or fir forests
	  • CO_2 emissions from burning 4 railcars' worth of coal
	  • CO_2 emissions from 322721 dm^3 of gasoline consumed

3.	Energy benefits: powering about 100 homes Factors used in the calculations: 0.0423 pounds methane/standard cubic foot methane 0.5 standard cubic feet methane/standard cubic foot landfill gas 1 012 Btu/standard cubic foot methane 11 700 Btu/kilowatt-hour (weighted average for engines, gas turbines and boilers/steam turbines) 1.32 pounds carbon dioxide/kilowatt-hour (estimated average electric power plant emissions rate for 2011) 0.12 pounds carbon dioxide/standard cubic foot natural gas 0.93 gross capacity factor for generation units of electricity projects (to account for availability and operating load) 0.85 net capacity factor for generation units of electricity projects (to account for availability, operating load and parasitic losses) 0.91 factor for power delivered to households for electricity projects (to account for transmissions and distribution losses) 21 Global Warming Potentials (GWP) 5.23 metric tons carbon dioxide equivalent per vehicle per year 4.69 metric tons carbon dioxide per acre of pine or fir forest per year 191.5 metric tons carbon dioxide per railcar of coal 0.43 metric tons dioxide per barrel of oil 0.00889 metric tons carbon dioxide per gallon of gasoline 11 476 kilowatt-hours per household (average annual electricity usage) Direct equivalent emissions reduced calculations for electricity generation projects: $MMTCO_2E/yr$=megawatts (MW) of generating capacity*0.93 [gross capacity factor]*(8.760 hours/year)*(1000 kilowatts/megawatt)*11 700 Btu/kilowatt-hour)/(1 012 Btu/standard cubic foot methane) *(0.0423 pounds methane/standard cubic foot methane)/(2 000 pounds/short ton)*(0.9072 metric tons/short ton)/(1E+06 metric tons/million metric tons)*21 GWP of methane Tons CH_4/yr=$MMTCO_2eq/yr$ *(1E+06 metric tons/million metric tons)/(0.9072 metric tons/short ton)/21 GWP of methane Avoided Equivalent emissions reduced calculations for electricity generation: MMTCO2eq/yr=MW of generating capacity*0.85 [net capacity factor] *(8 760 hours/year)*(1 000 kilowatt/megawatt)*(1.32 pounds carbon dioxide/kilowatt-hour)/(2 000 pounds/short ton)*(0.9072 metric tons/short ton)/(1E+06 metric tons/million metrics tons)*21 GWP of methane Tons CO_2/yr=$MMTCO_2eq/yr$*(1E+06metric tons/million metric tons)/(0.9072 metric tons/short ton)

compared to production based on coal and lignite. The emission of carbon dioxide from the tested engine is lower compared to the emission generated in the electricity production from lignite (Table 4). Unfortunately, it is quite the contrary when comparing these technologies with regards to nitric oxides, as it is higher in electricity production from landfill gas. From the comparison of the emissions from engines fueled with landfill gas and diesel oil we may conclude that the landfill gas fuel engine generates a lower amount of nitric oxides, sulfur dioxide but more carbon dioxide, carbon monoxide and hydrocarbons. The landfill gas fueled engine is much more favorable in terms of particulate matter emissions.

The use of landfill methane generated as a result of waste disposal brings a plethora of ecological benefits. One of them is the reduction of fossil fuel exploitation (crude oil, coal and natural gas). Methane is a greenhouse gas whose greenhouse potential is much greater than that of carbon dioxide. Hence, the use of this gas for the production of energy is contributed to the reduction of climatic changes and local smog.

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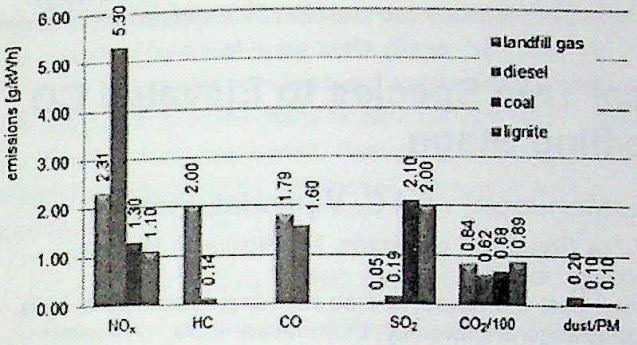

Fig.10. The emissions during the production of electricity from different fuels

The use of landfill gas improves the quality of air on a local scale. It is noteworthy too that burning of the landfill gas reduces the emission of non-methane organic compounds that occur in low concentrations in the gases emitted from the disposal sites, thus reducing the potential perils for human health and the ecosystem. Yet another benefit is the improvement of safety through a reduction of the risk of explosion of the accumulated gas.

Aside from the above mentioned direct results of the emission tests, ecological and energy related benefits from the operation of the tested power generator were assessed using a spreadsheet developed by the EPA (LFGG Benefits Calculator, 2011). The results of these calculations are presented in table 4.

CONCLUSIONS

The use of the municipal landfill gas in the power generator system has a variety of advantages. One of the most important is its relatively high efficiency and good ecological parameters. From the comparison to other methods of electricity production it is evident that a combustion engine fueled with municipal landfill gas has a lower or at least comparable emission of some of the components, which results from the combustion of fuels and its key advantage is the reduction of methane (a greenhouse gas of great greenhouse potential). The presented ecological and energy related benefits promote this type of solution and an additional motivation is the need to reach the 2020 target by Poland and other EU member states. It is noteworthy that obtaining electricity from renewable sources, including municipal landfill gas, is becoming a priority for the legislative authorities of the EU member states, which is also visible in the legal acts in Poland. To sum up, we should state that the application of landfill gas is a huge opportunity for the development of alternative energy engineering and an improvement for the condition of the natural environment.

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Physiological Response of Tropical Tree Species to Elevated CO_2 Levels at Seedling Stage

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Abstract: The increasing CO_2 concentration in the atmosphere levels often stimulates the photosynthesis and biomass. However, the duration and magnitude of this stimulation on physiological processes of tropical tree species is unknown. The objective of this experiment was to examine the physiological response of four commercially important tropical tree species to elevated CO_2 levels. *Tectona grandis* (teak), *Azadirachta indica* (neem), *Ailanthus excelsa* (maharukh) and *Bambusa bambos* (bamboo) seedlings were exposed to ambience (380 ppm) or elevated CO_2 (600 and 900 ppm) levels using an automated open top chamber (AOTC). The seedlings were exposed to elevated CO_2 levels for 180 days. Leaf gas exchange characters were measured in the second or third fully expanded leaves of the seedlings with a portable infra-red gas analyser (Li-Cor 6400XT) at the end of the study period. The elevated CO_2 levels significantly affected the physiological processes and did not show identical response in the studied tree species. Maharukh and bamboo plants were recorded optimistic response in terms of photosynthesis under elevated CO_2 even up to 900 ppm. Teak also registered a high photosynthesis up to 600 ppm level of CO_2, but it showed a decreased photosynthetic rate under 900 ppm of CO_2. Contrary to these three species, neem showed a negative response to the elevated CO_2 at both 600 and 900 ppm levels. The response of the species on transpiration (E) mmol $m^{-2}s^{-1}$ was similar to that of the photosynthetic rate (Pn). This study recommend that we should not generalise the response of tropical tree species to elevated CO_2. However, the commercially important tropical tree species should be assessed individually for the physiological functions to elevated CO_2.

Key Words: Automated open top chamber, Li-Cor, photosynthesis, CO_2, transpiration, tree physiology, neem, maharukh, teak, bamboo

Atmospheric CO_2 concentration has risen from a pre-industrial concentration of ~280 to 384ppm in 2008. It is predicted to reach ~550 ppm by 2050 and ~730 to 1020 ppm by 2100 (Solomon *et al.*, 2007). The predicted increasing CO_2 concentration in the atmosphere will affect both the current and future ecosystem processes at many stages of the organisation. It is very important to study the effects of increasing CO_2 levels ranging from molecular to global scale. It is a major challenge to realise the complex relationship between photosynthesis and yield (Gifford and Evans, 1981; Fichtner *et al.*, 1993), besides the interactions between plant growth and environment. Tropical forests play an important role in the global carbon cycle, accounting for about one-third of global primary productivity (Beer *et al.*, 2010; Lucas *et al.*, 2011). Compared to temperate tree species, little is known about the physiological responses of tropical tree species to elevated CO_2 (Korner, 2009). There is a debate on how the tropical tree species, particularly seedling, will respond to continuously increasing level of atmospheric CO_2 (Holtum and Winter, 2010; Lewis *et al.*, 2009; Wurth *et al.*, 1998).

Short-term experiments in tree species exposed to elevated CO_2 levels have shown that increased photosynthetic rate up to 40-80% in *Pinus ponderosa, P. radiata, Quercus coccinea* and *Populus deltoides* seedlings (Green and Wright, 1977) have increased net production by 20% (Couteaux and Bottner, 1996). Wang *et al.* (1998) reported 110% increased annual total net photosynthesis in elevated CO_2 than in an ambient CO_2 level. Short-term exposure of C_3 plants to elevated CO_2 concentrations often stimulates photosynthesis. It increases in biomass as a result of the improved competitiveness of CO_2 over O_2 as a substrate for the enzyme ribulose-1,5-bisphosphate carboxylase/oxygenase (Woodward *et al.*, 1991).

Researchers have recorded up-and-down-regulations of photosynthesis to elevated CO_2. Prasad *et al.* (2004) reported that the up-regulation of the carbohydrate metabolism resulted in greater accumulation and export of carbohydrates associated with photosynthesis, despite a decline in rubisco activity and protein content. Photosynthetic down-regulation in response to elevated CO_2 is also common in nutrient-poor soils, as it can affect photosynthesis. Progress has been made in determining the biochemical and molecular process by which photosynthesis is down-regulated in response to elevated CO_2. The photosynthetic down-regulation of leaf biochemicals was characterised by reduced chlorophyll and rubisco activity, limitations in RuBP and *Pi* regeneration,

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higher leaf mass/leaf area ratio and decreased leaf nitrogen concentration on a leaf mass basis (Sage, 1994; Tissue *et al.*, 1995). The studies on response of commercially important tree species at seedling stage to elevated CO_2, particularly in peninsular India are limited. Hence, an experiment was initiated to understand the physiological response of tropical seedlings using AOTC.

MATERIALS AND METHODS

Research was conducted using AOTC facility at Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore, India, located on 11°59'0.69" N, 76°57'2.32" E and 437 m MSL. Mean yearly temperature and rainfall at the site were maximum 35 °C, minimum 18.5°C and 503 mm, respectively. The chambers were cubical type structures of 3 x 3 x 3 m dimension, fabricated with galvanised iron pipe frames. The structures were covered with UV protected polyvinyl chloride sheet to have a transmittance of more than 95% of ambient photosynthetic active radiation. The upper portion of the chamber was kept open to maintain near-natural conditions. Elevated CO_2 conditions were achieved by injecting CO_2 gas (Food grade; Sakthi Gas Service, Coimbatore, India) at the bottom of the chamber from pressurised cylinders through valves. Ambient air was mixed with CO_2 and the gas mixture was dehumidified by passing through a passage filled with silica gel followed by soda lime. Temperature and humidity of the AOTC were measured with the inbuilt thermistor and capacitance sensors. In order to record, display and control the actual and desired CO_2 levels, relative humidity and temperature in each AOTC, data logger software called supervisory control and data acquisition (SCADA) was used. These conditions were monitored inside and outside the chambers during the study period on real-time basis by feedback control loop, which passed through programmable logical controllers (PLC).

The seedlings were grown on the mother bed according to the standard recommendations. Seedlings of ~3-4 weeks old with almost uniform size (10 to 25 cm) were transferred into polybags (30 x 20 cm). Treatments were imposed ~30-60 days after established seedlings of teak, neem, maharukh and bamboo tree in a completely randomised design. Seedlings were kept in a circle, 60 cm apart from each other and from the chamber walls. To reduce the boundary effect, the seedlings of the same seed lot surrounded by each AOTC. Seedlings were rotated within a chamber every week to minimise the effects of within the chamber variation in temperature, light and CO_2. Plants were watered daily with tap water (without any nutrients) or according to the need, throughout the experimental period and grown with day/night temperature regimes of prevailing weather conditions of Coimbatore. No artificial light was provided in the chamber.

The treatments included one ambient CO_2 concentration (approximately 382 ppm) outside the chamber which served as a control and four in AOTC. AOTCs were maintained as i) chamber control (ambient CO_2, temperature and relative humidity), ii) 600 ppm CO_2 + ambient temperature + ambient relative humidity, iii) 900 ppm CO_2 + ambient temperature + ambient relative humidity, and iv) 600 ppm CO_2 + temperature regulated through controlling of relative humidity. When CO_2 concentration of the AOTC was increased to 600 and 900 ppm, the temperature of the chamber also increased 2-4°C more than the ambient environment. To maintain the chamber's temperature as equal to ambient level, a custom-built humidifier unit was used. Level and uniformity of CO_2 distribution of each chamber were continuously checked using infra-red gas analyser (IRGA: Fuji Electric Systems Co. Ltd., Japan), which was calibrated regularly with reference CO_2 cylinders (400 and 800 ppm) throughout the experimental period.

Net photosynthetic rate (Pn), stomatal conductance (g_s), intercellular CO_2 concentration (Ci) and transpiration rate (E) were measured in the second or third fully expanded leaves. All these measurements were recorded in twelve plants per species and three replications per leaf using Li-COR 6400XT Portable Photosynthesis System (Li-Cor Instruments, USA) 180 days after the seedlings (totalling 210-240 days old) were exposed to elevated CO_2 concentrations. The measurements were performed at midday, between 1000 and 1300 eastern daytime, when the solar photosynthetic photon irradiance was saturated at 1000-1200 µmol m^{-2} s^{-1} under cloud free conditions. The photosynthetic chamber was calibrated at regular intervals using two reference CO_2 cylinders before taking the measurements. After the reference CO_2 concentration become stabilised (~5 min), the chamber CO_2 was matched to the reference CO_2 so that the chamber and reference CO_2 concentrations were equilibrated prior to a leaf being inserted into the chamber. The leaf was allowed to equilibrate for 5 min before measurements were taken and the duration of each measurement was usually 30-45 seconds. Air temperature was around 35°C during the measurement, and leaf temperature inside the cuvette ranged between 30 and 35°C. To minimise the heat load within the cuvette, a small external fan was used. The relative humidity at the inlet of the cuvette was kept between 60 and 80%. Water use efficiency (WUE) was calculated using net photosynthetic rate and transpiration (Pn/E) (Li *et al.*, 2004). Intrinsic water use efficiency (IWUE) was calculated as the ratio of the net photosynthetic rate to the stomatal conductance (Pn/gs). Intrinsic carboxylation efficiency (ICE)

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was derived as the ratio of the net photosynthetic rate of intercellular CO_2 concentration (Pn/Ci). The direct or short-term effect (STE) of increasing CO_2 concentration was quantified as the ratio of stomatal conductance (g_s) measured at elevated CO_2 concentration to the plant grown at the ambient growth conditions (Del Pozo *et al.*, 2005). A similar ratio was calculated for the net CO_2 assimilation rate (NAR), which was adopted from (Zhang *et al.*, 2008).

The data on 12 seedlings per treatment in three replications were subjected to analysis of variance (ANOVA) for completely randomised design in which $P<0.05$ was considered as significant. The software utilised for statistical analysis was IBM SPSS® version 20 for Windows™.

RESULTS AND DISCUSSION

The response of tropical species to elevated atmospheric CO_2 is impeded by the absence of experimental studies for intact tropical ecosystems. The present study was conducted to understand the physiological response of tropical seedlings to elevated CO_2 concentrations that are predicted to affect the tropical ecosystems in the year 2050 onwards. The effect of gas exchange parameters, which are measured in the seedlings grown in both ambient and elevated CO_2 conditions was highly significant in overall responses (Table 1).

The physiological response of teak seedlings were significantly influenced by elevated CO_2 levels as compared to counterparts in the ambient environment. The seedlings imposed to 600 ppm of CO_2, Pn (39.7 and 20.2%) and Ci (13.4 and 11.1%) significantly increased respectively with or without relative humidity. However, neem seedlings registered significantly higher Pn (17.6%) under chamber environments. Elevated levels of CO_2 (600 and 900 ppm CO_2) reduced Pn by 10.20 and 4.40% when compared to ambient ~382 ppm of CO_2. Maharukh seedlings showed less pronounced Pn than the ambient environment when they were treated with 600 and 900 ppm CO_2. But, within the chamber environment, the species responded positively to CO_2 enrichment in terms of increase in Pn, except the chamber treated with 600 ppm CO2 + RH, where the temperature was controlled by a humidifier. Bamboo seedlings showed a significantly positive response to elevated CO_2 levels. Highest Pn was recorded in 600 (3.40 µmol CO_2 m^{-2} s^{-1}), and 900 ppm of CO_2 (3.20 µmol CO_2 m^{-2} s^{-1}). Pn remained low in chamber environment and 600 ppm CO_2 + RH.

The range of Pn in tropical seedlings varied between 2.09 and 6.71 µmol CO_2 m^{-2} s^{-1}. There was an increased Pn in teak, maharukh and bamboo seedlings to 600 ppm CO_2 (over the chamber control/ambient), that resulted from improved competitiveness of CO_2 over O_2 in the carboxylation. Ci influences the Pn either by up-and-down-regulation, as obvious when an increased Pn (6.71 µmol CO_2 m^{-2} s^{-1}) was observed in teak by maintaining higher Ci (318.53 µmol CO_2 mol air^{-1}), whereas, increased Pn (4.41 and 4.82 µmol CO_2 m^{-2} s^{-1}) with lower Ci (254.94 and 211.85 µmol CO_2 mol air^{-1}) was observed in maharukh, followed by bamboo Pn 3.40 and 3.20 µmol CO_2 m^{-2} s^{-1} with Ci 234.80 and 224.35 µmol CO_2 mol air^{-1}, respectively at 600 and 900 ppm CO_2. This trend indicated that higher Pn in neem and maharukh seedlings is directly correlated with elevated CO_2 concentrations *viz.*, 600 and 900 ppm, which was attained by upholding lower Ci concentrations. Whereas, in bamboo, Pn declined from 3.40 to 3.20 µmol CO_2 m^{-2} s^{-1} at 600 and 900 ppm CO_2 concentrations because of inadequate Ci to meet maximum photosynthesis. This up-and-down-regulation in Pn at varied levels of Ci have been previously demonstrated by Ceulemans *et al.* (1999), Hsiao and Jackson (1999), Rogers and Ellsworth (2002). When additional carbohydrate support increased growth, there is a tendency for up-regulation, whereas when carbon is assimilated over a plant's ability to cause sinks, there is a tendency for down-regulation. The physiological response of tropical species to elevated CO_2 will depend, in part, on opportunities to start new sinks (Stitt, 1991; Amthor, 1995; Ceulemans *et al.*, 1999). This sink regulation of photosynthesis may be important in tropical species with a high capacity for carbon assimilation but low carbon use efficiency (Herold, 1980; Ng and Hew, 1999).

One of the most consistent responses of a plant to elevated CO_2 is an increase in WUE and involves the inherent ability of the plant to assimilate CO_2. Generally, the amount of carbon assimilated per unit water loss increase because g_s and E reduces under-elevated CO_2, whereas, Ci remains relatively constant (Marshall and Monserud, 1996). Therefore, more carbon is assimilated at a given E rate (Hsiao and Jackson, 1999). Thus, an increase in WUE is similar to some extent with a decrease in water stress (Amthor, 1999). Higher the ratio of WUE, better the ability for carbon assimilation. WUE is ranged between 21.36 and 73.01 µmol $mmol^{-1}$ in teak and maharukh seedlings, respectively, at 600 ppm CO_2 + RH and 900 ppm CO_2. Almost higher WUE registered by 900 ppm CO_2 in all the species studied except neem, increased in proportion with CO_2 levels and transpiration (E). Higher g_s often decreased WUE in the case of neem and maharukh trees due to increased elevated CO_2. A notable difference found in g_s but not stomatal aperture is the cause of increased transpiration. However, in teak, higher g_s increased WUE when compared within treatments because of lack of stomatal sensitivity in bamboo.

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Morison (1993) confirmed the trend where WUE increased invariably in elevated CO_2 which will lead to reduced gs and therefore transpiration. In the present study, g_s and g_r were directly correlated with transpiration and its influence on WUE and Pn. On transpiration, the displayed differences among treatments were significant P>0.01 for all the studied tree species. The differences in treatment with respect to g_s were statistically significant as well. The extent of this effect, however, is dependent on the experimental conditions. Field *et al.* (1995) found that g_s was reduced by 31% for plants in growth chambers, 17% for plants in open top chambers and 4% for plants grown in the soil. Decreases in g_s or E in elevated CO_2 were small or absent in mature trees (Dufrne *et al.*, 1993), seedlings (Heath and Kerstiens, 1997), and *Pinus taeda* (Ellsworth *et al.*, 1995). In *Picea sitchensis*, an increase in g_s was observed in elevated CO_2 (Barton *et al.*, 1993). It is obvious that, the g_s of many woody species were rather unresponsive to elevated CO_2. In such a case, the increase in WUE might be because of increased carbon assimilation rates (Eamus, 1996). An increase in WUE is probably the most common leaf level response to elevated CO_2, although changes in WUE are not necessarily linked with proportional changes in plant growth and Pn (Beerling *et al.*, 1996).

Higher the value of intrinsic water use efficiency (IWUE), better the efficiency of the plant to divert water for photosynthesis (Pn) than transpiration (E). The efficient control of water loss has been indicated by higher IWUE (Tuomela, 1997). IWUE of the present study ranged between 0.56 and 1.20 µmol mol^{-1}, respectively, in 600 ppm CO_2 + RH and ambient conditions of maharukh seedlings. However, observed higher IWUE 1.14 µmol mol^{-1} in neem at 900 ppm CO_2, which is notably 12.30% greater than the ambient condition. Results suggested that neem seedlings efficiently regulated water that was used for Pn than E even at higher CO_2 concentrations. RH significantly influenced the IWUE, when the species subjected to 600 ppm CO_2 + RH, consumed higher amounts of water for E rather Pn. Maharukh (112%) seedlings were found to be vulnerable to water loss followed by teak (95%), bamboo (87%) and neem (64%). The IWUE decreased when CO_2 concentrations increased because of lower Ci, and thus limiting the Pn through E.

Positive correlation existed between WUE, IWUE and Ci/Ca with Pn and Ci. This relationship indicated that the Ci and Pn of the seedlings were influenced by stomatal density, stomatal index and transpiration against given environmental conditions. Woodward (2000) found out the correlation between stomata density found on the leaf surface and atmospheric CO_2 concentration. Stomatal density declined in response to increasing CO_2 concentration. The differences observed in the species response were because of the differences in CO_2 concentrations at different temperatures and RH maintained in AOTCs. This is primarily due to competitive carboxylation and oxygenation reactions catalysed by Rubisco and limitation of stomatal functioning at cellular levels of CO_2 and O_2 concentration. The rate of the oxygenation reaction (photorespiration) increases more rapidly than the carboxylation reaction as temperature rises and CO_2 is also less soluble than O_2 at higher temperatures (Lambers *et al.*, 1998). Thus, under elevated CO_2, higher temperatures are less inhibitory because the substrate concentration in the carboxylation reaction is proportionally increased.

The plants having a higher intrinsic carboxylation efficiency (ICE) showed better efficiency for carboxylation. In the present study, higher ICE was recorded by *Ailanthus* 0.023 µmol m^{-2} s^{-1} at 900 ppm CO_2 followed by teak 0.021 µmol m^{-2} s^{-1} at 600 ppm CO_2 and this ratio ranged between 0.007 and 0.023 µmol m^{-2} s^{-1}. The ICE was increased over ambient with *Ailanthus* (5.93 to 27.94 %) when 600 and 900 ppm CO_2 were imposed to seedlings. In contrast, teak seedlings responded reversely, where it declined from 29.00 to -39.91% when the CO_2 concentration was increased. There was no change in ICE of neem (0.007 µmol m^{-2} s^{-1}) at both 600 and 900 ppm CO_2 and was at par in the case of bamboo (0.015 µmol m^{-2} s^{-1}). RH (600 ppm CO_2 + RH) significantly influences the ICE of all the tree species when compared to chamber control, 600 ppm CO_2 or ambient conditions.

Short-term responses of tropical seedlings to elevated CO_2 was also observed. The short-term or direct response to elevated CO_2 caused a smaller reduction of g_s in bamboo 10.66-15.82% but a greater in Pn (17.70 and 12.54%), showing that the decrease in g_s in response to increased CO_2 is more than compensated by the larger substrate for carboxylation (Del Pozo *et al.*, 2005). Acclimation can be detected as a growth CO_2 concentration effect on values of g_s measured under similar environmental conditions (Bunce, 2001). The limited CO_2 enrichment experiments have reported g_s acclamatory effects to elevated CO_2. The degree of acclimation of g_s in the present study are similar with Zhou *et al.* (2005), who found that g_s of *Pinus sylvestriformis* was 22% lower in plants grown under elevated CO_2 compared with ambient CO_2 grown plants. By contrast, Li *et al.* (2003) have reported that growth in elevated CO_2 had no effect on g_s of *Quercus myrtifolia*. Such variable patterns of g_s acclamatory may indicate that the length of the exposure to elevated CO_2 or different environmental conditions or differences between species can account for

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Table 1. Effect of elevated CO_2 on physiological responses of fully expanded leaves in tropical species for 180 days under ambient or elevated CO_2 concentrations.

Species/Treatments	Pn	Ci	E	g_s	Ci/Ca	WUE	IWUE	ICE	g_r	STE	NAR
Teak											
Ambient	4.04	275.83	3.87	0.09	0.72	48.08	1.03	0.015	0.91	-	-
Chamber control	2.40	268.27	4.13	0.06	0.71	42.54	0.59	0.009	0.94	0.66	0.59
600 ppm CO2	6.71*	318.53*	6.89*	0.27*	0.84*	26.56	1.00	0.021*	0.73	3.05	1.66
600 ppm CO2+ RH	5.07*	310.27*	10.29*	0.30*	0.82*	21.36	0.53	0.016	0.70	3.37	1.25
900 ppm CO2	2.66	243.39	3.86	0.05	0.65	54.81	0.69	0.011	0.95	0.55	0.66
SE	0.22	8.13	0.64	0.03	0.02	4.51	0.07	0.001	0.03	-	-
CD (0.01)	0.58	21.62	1.69	0.07	0.06	12.00	0.18	0.002	0.07	-	-
Neem											
Ambient	2.46	272.49	2.46	0.05	0.71	51.85	1.00	0.009	0.95	-	-
Chamber control	2.98*	288.44*	3.41*	0.07*	0.74*	43.60	0.88	0.010*	0.93	1.06	1.21
600 ppm CO2	2.23	316.49*	2.21	0.07*	0.81*	32.36	1.00	0.007	0.93	1.16	0.91
600 ppm CO2+ RH	2.19	272.17	3.50*	0.06*	0.74*	38.27	0.61	0.008	0.94	1.00	0.89
900 ppm CO2	2.35	326.03*	2.02	0.08*	0.84*	28.66	1.14	0.007	0.92	1.20	0.96
SE	0.08	4.01	0.14	0.00	0.01	2.16	0.08	0.000	0.00	-	-
CD (0.01)	0.20	10.65	0.37	0.01	0.03	5.75	0.22	0.001	0.01	-	-
Maharukh											
Ambient	4.71	287.48	3.95	0.11	0.76	43.57	1.20	0.016	0.89	-	-
Chamber control	3.10	272.78	5.01*	0.08	0.72	41.43	0.62	0.012	0.92*	0.67	0.66
600 ppm CO2	4.41	254.94	4.54*	0.08	0.69	53.48*	0.97	0.017	0.92*	0.72	0.94
600 ppm CO2+ RH	2.73	271.75	4.82*	0.07	0.74	36.71	0.56	0.010	0.93*	0.65	0.58
900 ppm CO2	4.82	211.85	5.25*	0.07	0.57	73.01*	0.92	0.023*	0.93*	0.58	1.02
SE	0.18	6.01	0.19	0.01	0.02	3.50	0.04	0.001	0.01	-	-
CD (0.01)	0.47	15.99	0.51	0.02	0.04	9.32	0.11	0.002	0.02	-	-
Bamboo											
Ambient	2.80	259.84	2.57	0.05	0.67	59.96	1.16	0.011	0.95	-	-
Chamber control	2.58	244.50	3.48*	0.05	0.65	55.57	0.75	0.011	0.95	0.94	0.92
600 ppm CO2	3.40*	234.80	3.43*	0.05	0.64	63.34	1.00	0.015*	0.95	0.90	1.22
600 ppm CO2+ RH	2.09	254.47	3.46*	0.05	0.69	45.82	0.62	0.008	0.95	0.98	0.75
900 ppm CO2	3.20*	224.35	3.73*	0.05	0.61	63.53	0.87	0.014*	0.95	0.86	1.14
SE	0.12	7.85	0.28	0.00	0.02	5.23	0.08	0.001	0.00	-	-
CD	0.33	20.89	0.75	0.01	0.06	13.91	0.21	0.002	0.01	-	-

*The photosynthesis (Pn) µmol CO_2 m^{-2} s^{-1}, intercellular CO2 concentration (Ci) µmol mol^{-1}, transpiration (E) mmol m^{-2} s^{-1}, Stomatal conductance (g_s) mmol m^{-2} s^{-1}, ratio of intercellular CO_2 concentration and ambient CO_2 concentration (Ci/Ca), water using efficiency (WUE) µmol mol^{-1}, Intrinsic water use efficiency (IWUE) µmol mol^{-1}, intrinsic carboxylation efficiency (ICE) µmol m^{-2} s^{-1} (µL L^{-1})$^{-1}$, stomatal resistance (g_r) mmol m^{-2} s^{-1}, direct or short-term effect (STE) and net CO_2 assimilation rate (NAR).

the contrasting results. Following a decrease in g_s with a continuing rise in the atmospheric CO_2, many C_3 plants will use less water and become more efficient in water use. The reduced g_s recorded in plants grown in elevated CO_2 is presumably caused by a developmental (indirect) effect of CO_2 rather than by a direct CO_2 enrichment effect on the stomatal aperture, resulting in a reduction in the leaf E and, thus, an improvement in WUE and in the tissue water status (Darke *et al.*, 1997; Jarvis *et al.*, 1999; Vu, 2005).

Observations on physiological parameters were recorded in one set of climatic conditions. In other words, the observations were made during the summer. Similar studies need to be conducted at different seasons and the changes in physiological processes have to be observed in order to conclude on the species level response to elevated CO_2, as the various climatic features like sunshine, rainfall, humidity, temperature, wind, etc. also greatly change the physiological processes in the plant systems.

CONCLUSION

The present study outlined the physiological response of tropical species to the elevated CO_2 levels under simulated temperature and moisture regimes, primarily at seedling stage. Statistical analysis showed substantial variation in

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photosynthesis (P>0.01) when seedlings of the tree species were exposed to various CO_2 levels. *Ailanthus* seedlings have registered greater Pn in ambient environment than in chamber environments. Teak and bamboo seedlings registered a higher photosynthetic rate in a chamber with elevated CO_2 concentration at 600 ppm. High temperature in a chamber environment favoured greater photosynthesis in neem. The physiological response of commercially important tropical tree species need to be evaluated individually to understand the physiological and biochemical metabolisms, since the species included in the study that showed up-and-down regulated activities to the elevated levels of CO_2. In this context, the 'Automated Open Top Chambers' can be used for evaluation of selected tree genotypes for enhanced CO_2 sequestration under elevated levels of CO_2 as well as temperature.

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Land Resources Appraisal Using Satellite Remote Sensing and GIS: A Case Study of Rajni Devi Sub-watershed (District Hoshiarpur)

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Abstract: In the present study of Rajni Devi sub-watershed, focus was on the drainage parameters and their impact on the land use of the basin. Satellite remote sensing and GIS have been used to map the various land use classes along with drainage parameters. Ten land use/land cover classes have been identified at level III and the stream is of sixth order. The 0.63 value of elongation ratio in the study area showed it to be slightly elongated basin and the concentration time of flow is high, resulting deposition of the solids along the choes.

Key Words: Drainage parameters, land use, remote sensing, GIS

A watershed is a natural hydrological unit and is considered more rational for land and water recourses development because its resources have optimum and synergetic interaction. Remote sensing and GIS jointly provide geo-informatics support in terms of relevant, reliable and timely information needed for economic development and environmental planning (Ashenafi *et al.*, 2013; Iqbal *et al.*, 2013). The qualitative analysis of drainage network enables relationship between different aspects of the drainage pattern of the basin in numerical terms (Nageswara *et al.*, 2010). The Punjab sizeable area is covered by Shiwalik foot hills and these shiwalik watersheds have three distinct problematic areas. The up landed area mostly non-arable, middle reach having undulating topography with combination of arable and non-arable land and lower areas which are arable with better soils.

The repeated deposition of coarse sediments in the piedmont plains renders these areas comparatively low in agricultural productivity. These degraded lands not only represent a locked up production potential but also pose serious-economic problems. In order to restore such degraded lands for productive purposes and control their spread, a comprehensive strategy for survey, monitoring and planning is warranted. Before planning soil conservation strategies and a forestation in the Shiwalik hills, it is essential to collect detailed information about the land and water management problems, land use; nature of soils and extent of erosion, etc. Land and water management on watershed management basis with adequate database has no substitute. Spatial distribution of resources in the form of maps will help to understand the interrelationship of various resources. In the present investigation, Rajni Devi Sub-watershed of Hoshiarpur district has been selected for detailed land use mapping and drainage characteristics.

MATERIALS AND METHODS

The Rajni Devi sub-watershed lies between Latitudes of 31°24'25" to 31°30' 43" North and Longitudes of 75°59'50" to 76°7'30" East. It covers a total geographical area of 5698 hectares falling in villages Bachhohi, Rajni Devi, Badhan, Tajewal, Sarangwal, Bajwara, Jandoli, Ghokhar, Lehli Khurd, Parsowal, Bhulewal, Rathan, Chak Mallan, Chanthu Brahamna, Singhpur and Handowal. The sub-watershed comprises of gentle sloping Shiwalik hills, gentle to moderately sloping piedmont plain and seasonal 'rivulets' or 'choes'. The hills are located in the northeastern and eastern part and the plains occur in the north, south and western part of the study area. The altitude of the region varies from 310 meters, in the plains to 580 meters, above mean sea level in the hills. The hilly terrain covers nearly 42% of the total geographical area and is covered with moderately dense to dense forest. The climate of area is semi-arid to sub-humid, with annual rainfall between 64 and 117 cm annum^{-1}. Most of the rain occurs in monsoon season and hilly areas receive higher rainfall as compared to the plain areas. A great amount of rainfall goes waste as run off causing floods and severe soil erosion due to lack of infiltration and vegetation cover. The highest temperature (38.1°C) occurs in the month of June and lowest (6.1°C) in January.

Administrative boundaries viz. district, village boundaries were taken from the revenue maps published by Director, Land Records, Punjab. The High resolution (Cartosat-1 Pan & LISS- IV MX merged) digital satellite data of 2010 was on screen interpreted using ARC GIS software. Various photo-elements like shape, size, association, pattern, tone, texture, colour etc. were used to identify the various land use categories and drainage network. Well defined boundaries of agricultural land, bright cyan coloured

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settlements, dark colored water bodies and bright red coloured forests were clearly observed in the image. Adequate ground truth was collected to substantiate the result and the map was finalized after making necessary modifications. The area for different land use classes, drainage length, watershed area and other drainage parameters were calculated.

RESULTS AND DISCUSSION

Land use/land cover of the study area: The land use/land cover in the study area to a large extent is controlled by parent material, physiography and climate. There are ten land use/land cover classes identified at level III in the study area as rural settlements, hemlets, cropland, orchards, plantations, forest land and wastelands with or without scrub, choes, brick kilns and ponds (Fig.1).

Built-up land: Rural settlements and the hamlets are built categories present in the region. The rural built-up cover an area of 149.92 ha, which is 2.66 per cent of the TGA (total geographical area) of the sub-watershed while small hamlets scattered over the watershed cover an area of 38.06 ha collectively and contribute 0.67 per cent to the total area of watershed. The region has a well developed road network of main road, secondary roads and cart tracks.

Agricultural land: The agricultural land consists of cropland, orchards and plantations. It covers an area of 2746.47 ha, which is 48.64 per cent of TGA.Wheat, paddy, maize and fodder are the main crops of the region. The area is both tubewell irrigated and rainfed. Kinoo and mango are the main fruit species and poplar is the main plantation species present in the study area.

Forest land: The study area has got a very good forest cover, which is located in the hilly region and is of deciduous type and cover an area of 2403.77 ha. This is 42.57 per cent of the total geographical area. The main species of forest vegetation include *Acacia catechu* (khair), *Acacia nilotica* (kikar), *Dalbergia sissoo* (tahli), scrub and grasses.

Wasteland: The area especially adjoining the choes is covered by wasteland, which at some places is covered by scrub. This is due to the erosion and deposition of choes by fluvial action. The sub-watersheds wasteland covers an area of 234.07 ha, which is 4.14 per cent of the total geographical area. The mining area of brick kilns was the other category mapped and covered an area of 25.57 ha (0.45% of total area).

Water bodies: Seasonal choes and village ponds were the water bodies mapped in the entire sub-watershed. A part of original course of the Rajni Devi choe is presently non-existent because of the expansion of cropland and settlements. Choes cover total area of 48.49 ha, which is 0.86 per cent of the total geographical area. The drainage of maximum order of 6 is present in the study area. The area covered by village ponds was very small and only 0.81 ha.

Drainage Pattern and Characteristics of Study Area

The shape of basins affects stream flow hydrographs and peak flows. The important parameters describing the shape of the basin are form factor (Rf), circulatory ratio (Rc) and elongation ratio (Re). The various characteristics of the Drainage basin which were calculated are:-

a. Size of the basin (Area) = 56.50 km²

b. Shape of the watershed: - It governs the rate at which

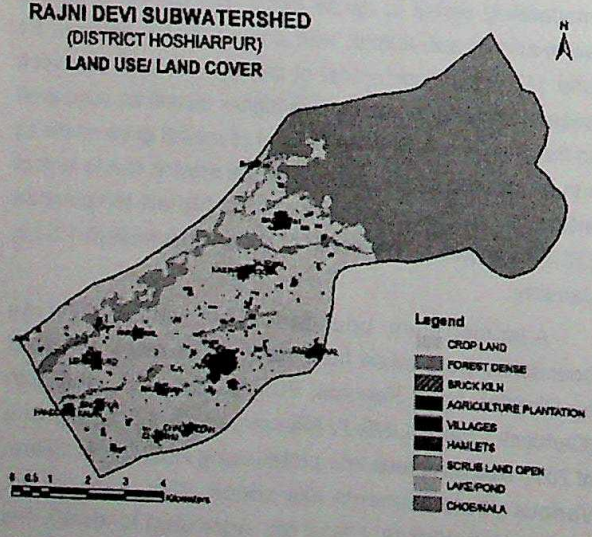

Fig. 1. Land use and land cover of Rajni Devi Sub-Watershed of 2010 year

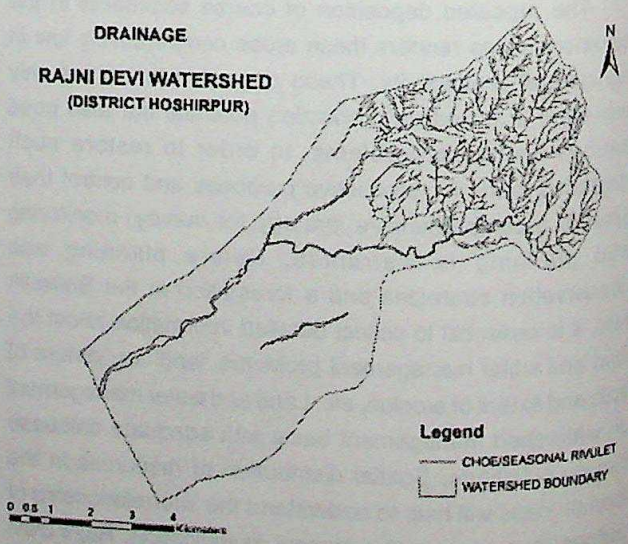

Fig. 2. Drainage map of Rajni Devi Sub-Watershed of 2010 year

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water enters the stream. It is expressed in the form factor and compactness ratio.

b.1 Form factor (R_f):Form factor is defined as the ratio of the watershed area (A) to square of watershed length.

= B/L = Area / Length^2

= 56.50 km^2 / (13.4)^2 km^2 = 0.32.

b.2 Compactness coefficient (C_c): Compactness coefficient is computed as ratio of watershed perimeter to perimeter of circle of watershed area.

= Perimeter/Circumference = P/2*A

=37558.945/2$\sqrt{\Lambda}$ *5650565

c. Elongation ratio (Re): Elongation ratio (Re) is the ratio between the diameter of the circle having the same area (as that of the basin) and the maximum length of the basin (Schumm 1956).

Elongation ratio (Re) is

Re = √56.50/3.14 * 2/13.4

= 0.63

Drainage pattern: The watershed is of fern type shape (Fig.2). The drainage network of the catchment's is gentle and the concentration time of the flow is high, resulting deposition of the solids along the bed sides in the watershed resulting increase in the wasteland area.

The factors describing the characteristics of the drainage are:-

i) Order of the streams = 6th

ii) Length of the streams (L) = 128.748

iii) Stream density (D_s) = No. of streams/total area km^2= 803/56.5 = 14.21 km^{-2}

iv) Drainage density (D_d) = L/A= Total length of the streams/ total area of the watershed km^2 = 128.7/56.5=2.27 km^{-1}

v) Circularity ratio (R_c): Circularity ratio was computed as the ratio between the basin area (A) to the area of the circle (A_c) having the same perimeter of the basin (L_p). = 56.50km^2/224.5 km^2 = 14.3

vi) Bifurcation ratio: The term bifurcation ratio (Rb) is used to express the ratio of the number of streams of any given order to the number of streams in the next higher order. The first order streams are those which have no tributaries. The second order streams are those which have only first order streams as tributaries. Similarly, the third order streams receive first and second order streams as tributaries and so on.

When the logarithm of number of streams is plotted against order, the drainage network shows a linear relationship and the plot on a semi logarithm paper (number of streams on the logarithm scale and the order on the linear scale) is nearly a straight line. The average value of the bifurcation ratio can be calculated by determining the slope of the regression line of logarithm of stream number (ordinate) and stream order.

The regression coefficient is identical with the logarithm of the bifurcation ratio (Fig.3). The slope of the fitted regression line give the average value of bifurcation ratio (Rb) and for Rajni Devi sub-watershed this comes out to be 8.3 (regression coefficient R^2 = 0.902).The lower bifurcation ratio values are characteristics of the watersheds that have suffered less structural disturbance and the drainage pattern has not been distorted because of the structural disturbances. The Rb values range varies from 3 to 5 in such areas. The Rb values computed in Rajni Devi sub-watershed indicate that the drainage has been affected by the structural disturbances suffered by the area.

Stream length: The cumulative length of stream of a particular order is measured and the mean length (Lu) of that order stream (u) is obtained by dividing cumulative stream length by numbers of segments of that order (Nu). The mean lengths computed for Rajni Devi is given in Table 1. In the present study, it is observed that the points lie in a straight line except the points corresponding to the third order streams. This is not necessarily due to the failure of Horton's law of streams length but may be due to the measurement errors. If larger scale photographs are used a better relation will emerge. In the present study, an attempt has been made to establish the relation between the stream order (u) and the cumulative stream length ($\Sigma_1^u \Sigma_1^{nu}$ Lu). The plot of logarithm of cumulative stream length along ordinate and stream order along abscissa for Rajni Devi gives a straight line fit. The straight line fit indicates that the ratio between Lu and u is constant throughout the successive

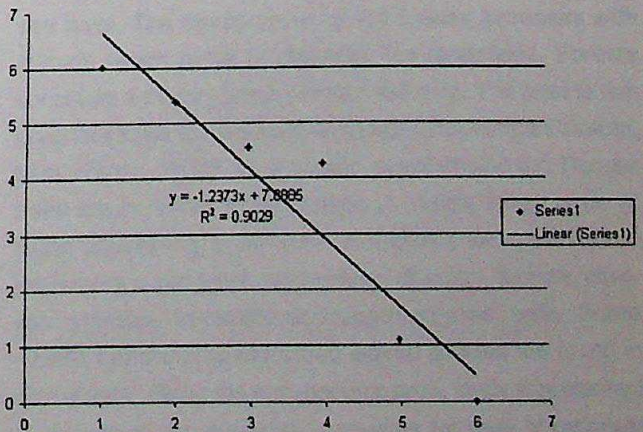

Fig. 3. Regression coefficient of bifurcation ratio of Rajni Devi sub-watershed

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Table 1. Mean length of Rajni Devi sub-watershed

Rajni Devi sub-watershed		1st	2nd	3rd	4th	5th	6th
a)	Stream length (km)	80.77	27.563	13.343	7.06	0.09	0
b)	Number of streams	411	222	96	71	3	1

order of a basin and suggest that geometrical similarity is preserved in basins of increasing order.

The factors controlling streams length are resistance to weathering and permeability of rock formation apart from the climate and other factors like vegetation. In general, low drainage density is observed in regions of highly resistant or permeable soil material under dense vegetative cover and low relief. High drainage density observed the regions of weak and impermeable subsurface material and sparse vegetation and mountainous relief. In the present study area, the low values in spite of mountainous relief indicate that the area is covered by resistant permeable rocks with a dense vegetative cover. Constant of channel maintenance are inverse of drainage density. The calculated values of morphometric parameters of Rajni Devi sub-watersheds are given in Table 2.

Table 2. Morphometric parameters of Rajni Devi sub-watershed

	Description	Rajni Devi sub-watershed
1	Rb (4th/5th order)	23.67
2	Constant of maintenance (1/Dd)	0.44

The morphometric parameters evaluated using remote sensing and GIS is found to be of immense use in better understanding the landforms, their processes and drainage pattern. The bifurcation ratios computed in the study indicated that the drainage has been affected by the tectonic disturbances and due to high concentration time of flow, solids deposit along the bed sides resulting excess of wastelands along the choes. A part of the original natural drains have eloped due to agricultural practices. The project has demonstrated that visual interpretation and mapping of satellite imagery in conjunction with information obtained from field checking can be advantageously used to prepare detailed drainage and land use/ land cover maps with acceptable accuracy and is essential for integrated and everlasting development of a sub-watershed.

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Indian Journal of Ecology

Exploration of Plant Based Ethno-Botanical Knowledge of Rural Community: Basis for Biodiversity Conservation

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Abstract: Human beings derive their food and many of their medicines and industrial products from both domesticated and wild forms of biodiversity. Medicinal and aromatic plants are subject to over exploitation due to increasing global demand and therefore require urgent conservation efforts. This study highlights the traditional use of' medicinal and aromatic plants for health care by the rural communities of the Ramban Forest Division of Jammu and Kashmir, India. Extensive field surveys were carried out in various locations of the study area, starting from the lower elevation of 740m up to 3600 m, above mean sea level in both Ramban and Banihal ranges of the division. A large number of shepherds, desi-hakims, pansaris and traders were interviewed accompanied by the field observations and voucher specimen collection. Altogether, 73 species of medicinal and aromatic plants belonging to 62 genera and 43 families were collected and documented. 67 species of 57 genera under 40 families were angiosperms while 6 species belonging to 5 genera of 3 families were gymnosperms implying that angiosperms dominate the vegetation of the area. The information gathered reveals that a number of ailments ranging from mild fever, stomach ache, cough and asthma and critical diseases like kidney trouble and cancer could be cured using these medicinal plants. These findings could contribute in pharmaceutical sector by directing further investigation of bioactive compounds in these medicinal plants. The information will give clues for conservation strategies of forest resources in the region including traditional kmowledge.

Key Words: Medicinal and aromatic plants, ethno-botany, diversity, survey, Ramban forest division

Forests have been playing key roles in the lives of people by moderating, climate, maintaining soil mantle, improving the soil fertility, minimizing soil erosion, purifying the air, preservation of wild life and regulating the flow of in rivers and streams (Kala, 2004). Forests also provide us timber, fuel wood, fodder and other non- timber minor products. Besides this forests provide numerous products for food and medicine. Amongst these resources medicinal and aromatic plants play very important role in the life support system and well being of the mankind.

The ethnic races and tribal people of the study area include Gujjars, Bakerwals and Gaddies, which have their own cultures, customs, religions, rites, taboos, myths, folk tales, songs, food and medicinal practices. Numerous wild and cultivated plants play an important and vital role among these cultures and this inter-relationship has evolved over generations of experience and practice (Maheswari, 1983). The accomplishment of forest dwellers in understanding plants and properties of their roots, stems, leaves, flowers and fruits is simply a result of long and intimate association with the flora and their dependence on them. Since their knowledge is based on experimentation on human beings though highly empirical, it warrants careful consideration of behove us to take advantage of their knowledge that still exists in many parts of the world for scientific scrutiny and adoption for posterity and should not be forgotten under the debris of modernism (Khan and Khanum, 2005).

Revival of the traditional medicine system in India and abroad has put extra assurance on the forests especially the medicinal plants. Out of 17,500 flowering plants species found in India, over 1600 are used in traditional medicine systems (MOEF, 1993). Over exploitation, unscientific harvesting and habitat degradation have led to extinction of more than 150 plant species in the wild. Some of the species which are in great demand from various pharmaceutical companies include *Saussurea costus, Aconitum heterophyllum, Picrorhiza Kurroa, Podophyllum hexandrum,* etc. (Uniyal *et al.*, 2002).

Forest vegetation of the study area mainly extends between altitudes of 950 meters to 4000 meters above mean sea level. The dense cover of the forests increases with altitude which helps in checking the landslides. Forests constitute a major portion of total land area. The area is rich in various kinds of medicinal herbs like patis, kuth, bankakari, karu, chairta, dhoop, mushki-bala, prambchalan etc. Deodar trees are in higher concentration in middle range while at higher covers fir and kail are in abundance along with broad leaved trees like kikar, kakarshing, dhaman, kharak, olive, etc. whereas, in middle and upper regions, oaks, horse chestnut and walnut are broad leaved species are found in abundance. Being the rich resource area, study was planned to document the available resources for their appropriate conservation and judicious utilization.

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MATERIAL AND METHODS

The problem of biodiversity loss is quite severe in the western Himalayas states due to the large scale trans humane activity of migratory cattle and local biotic pressures for fuel wood, fodder, and medicinal plants and overgrazing. Despite ongoing, socio-cultural transformation in the Himalayan region, local communities still have invaluable knowledge of plants and their uses. Therefore, there is need to documentation and rehabilitation of these degraded forests for understanding ecosystem function and biodiversity (Kaur and Joshi, 2010). Owing to enormous size and elevation, the Himalayas represent a complete transition from sub-tropical to temperate conditions. The state of Jammu and Kashmir in the lap of North-Western Himalayas, which is known to be a reservoir of about medicinal plants species. Western Himalayas of J&K including the study area of Ramban forest division has great plant diversity. The region represents ethno-botanical wealth, which has not been systematically surveyed for their judicious use and conservation. A lot of genetic diversity has already been eroded due to unscientific exploitation, the construction of various hydroelectric projects and other developmental activities. Keeping above in view, the study has been carried in Ramban forest division, which falls mainly under the geographical jurisdiction of district Ramban of Jammu Province of Jammu & Kashmir State. It has a total area of 77 hectare. The study area lies within 33°9'5" to 33° 32'26" North latitude and 75°0'39" to 75°25'8" East Longitude. The tract has highly mountainous and rugged topography comprising high ranges and deep valleys, flat or gently sloping meadows, steep slopes with great variation from 640 meters above mean sea level at the point where divisional boundary lies with Mahore forest division, which merges into Chenab to about 4553 meters above mean sea level at Monimal highest peak of the division on Pir Panchal Range (Working Plan, 1985, J&K State Forest Department)

The methodology adopted for the field surveys, data collection and analysis of the information was collected as per the requirement of the study. Extensive field surveys were carried out in various parts of the study area, starting from the lower elevation of about 740 m to 3600 m above mean sea level in both Ramban and Banihal ranges of the division. The altitudes of the different locations of the study area were measured by using Global Positioning System (GPS). The collections of voucher specimens were carried out during flowering/fruiting period to facilitate the process of identification. Only angiosperms and woody gymnosperms species of the medicinal and ethno-botanical importance have been collected. Identification of the collected specimens was done according to the Bentham and Hooker's system of classification. The specimens thus collected were processed i.e. pressed, dried by keeping in filter paper and changed periodically. The specimens were poisoned with naphthalene powder to provide protection against insect and fungal attack before mounting on the Herbarium sheets and deposited for future records, collected specimens of medicinal and aromatic plants were given the scientific names and local or common names and placed in respective families. Locality and description have also been documented along with their therapeutic uses.

The information regarding the traditional knowledge, local names and uses of the plants of the study area, parts used, purpose for which used, mode of administration and curative properties have been obtained through interviews and discussions with gujjars, bakarwals, shephards, elderly people, local hakims, traders/their helpers and have been appropriately documented in this study. Economy of the study area is basically agrarian and over 90 per cent of people are engaged in agriculture and horticulture. As only about 5% area of district Ramban is under irrigation, therefore, agriculture crop production depends on rainfall, if there is no rainfall in the months of April, May and June i.e. before monsoon arrival, the crop fails, particularly in the lower Kandi belt.

RESULTS AND DISCUSSION

The local communities in both the forest and non-forested areas of the division were found to use plants for curing various diseases of man and animals. Altogether a total of 73 plants species belonging to 43 families distributed over 62 genera were recorded in the study area. Out of the 43 families recorded with medicinal properties, the dominating families include: Rosaceae (5 genera and 7 species), Lamiaceae (5 genera and 6 species), Polygonaceae (3 genera and 5 species), Asteraceae (3 genera and 3 species), Scrophulariaceae (3 genera and 3 species), Ructaceae and Urticaceae (2 genera and species each), Geraniaceae and Maxaceae (1 genera and 3 species each), Lerberidaceae and Malvaceae (1 genus and 2 species each) and all remaining 31 families have one genus and one species each. For curing disease, use of both the above and below ground plant parts was reported in the study areas. Various plant parts utilized include leaf, fruit, bark, dot and others. Leaves were found to be mostly used for causing ailments in the study area. The other category includes flower, seed, stem, twig, latex and whole plant. The ample use of leaves is due to its continuous temporal availability, which has been reported by workers. The plentiful use of leaves can ensure sustainable harvesting of

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Table 1. Medicinal plants and their relative importance in the study area

S. No.	Species	Local name	Habit	Family	Parts used	Ethno-botanical uses (Ailments)
1.	*Abies pindrow* Royle	Raile	Tree	Pinaceae	Leaf, barks, cones	Tea, cough, phthisis
2.	*Aconitum heterophyllum* Wall.	Patish	Herb	Ranunculaceae	Root	Fever, abdominal pains
3.	*Achyranthers aspera* L.	Puthkanta	Herb	Amaranthaceae	Leaf, stem	Killing ticks and mites
4.	*Adhadota vasica* Nees	Basuti	Shrub	Acanthaceae	Leaf, flower, bark roots	Expectorant, antispasmodic
5.	*Ajuga bracteosa* Wall. ex. Benth	Chethor	Herb	Lamiaceae	Leaf	Fever pneumonia and excess bile
6.	*Anisomeles indica* L.	Dard jadi	Herb	Lamiaceae	Whole plant	Toothache
7.	*Arnebia benthamii* (Wall ex D. Don) Johnston	Johnston/ Toathvan	Herb	Asplemiaceae	Leaves, stem	Breast and teats infection
8.	*Berberis aristata* DC.	Paharishamal	Shrub	Berberidaceae	Root, bark, fruit	Laxative, eye and skin diseases
9.	*Berberis lycium* Royle	Shamal	Shrub	Berberidaceae	Stem, roots and fruit	Laxative and eye tonic
10.	*Bergenia liqulata* (Wall) Engl L.	Arali	Herb	saxifragaceae	Root	Quick healing of wounds
11.	*Betula utilis* D. Don	Burge	Tree	Betulaceae	Bark	Roofing material, antiseptic
12.	*Bistorta amplexicaulis* Greene (Basionym)	Zarathie	Herb	Polygonaceae	Root	Tea, joint pain
13.	*Buddleja paniculata* wall	Shungria	Shrub	Scrophulariaceae	Root	Making children healty
14.	*Calotropis rocera* L.	Aak	Shrub	Asclepiadaceae	Wholeplant	Toothache, anthelmintic
15.	*Cannabis sativa* Unn.	Bhang	Herb	Cannabinaceae	Whole plant	Sedative analgesic
16.	*Cedrus deodara* (roxb. Ex D. Don) G. Don	Dayar	Tree	Pinaceaeeae	Wood	Killing ticks remits
17.	*Colebrookia oppositifolia* Smith	Sloli	Shrub	Lamiaceae	Leaf	Blood clothing
18.	*Corydalis govaniana* Wall.	Gadi booti	Herb	Fumariaceae	Root	Diuretic, muscular and gastric pains
19.	*Cuscuta reflexa* Roxb.	Amalu	Creeper	Convolvulaceae	Stem	Increasing milk production
20.	*Debregeasia salicifolia* (D.Don) Findle	Sainsaru	Shrub	Urticaceae	Leaf	Dysentery and diarrhea of animals
21.	*Ficus carica* L.	Fagvoda	Tree	Moraceae	Leaf, stem, fruit	Spine removal laxative
22.	*Ficus roxburghii* Wall.	Trimal	Tree	Moraceae	Fruit	Laxative, appetizer
23.	*Ficus palmate* Forsk.	Fagorie	Tree	Moraceae	Fruit, leaf, stem	Spineremoval, laxative emollient
24.	*Fragaria nubicola* Lindey exlacaita	hinglechu	herb	Rosaceae	Root, fruit	Joints pain, appetizer
25.	*Geranium nepalense* sweet	Gurda gadi	Herb	Gerniaceare	Whole plant	Kidney diseases, dying medicinal preparations
26.	*Geranium pratense* L.	Ratnal	Herb	Geaniaceare	Root	Blood purification healing wounds
27.	*Geranium wallichianum* D. Donar Sweet	Sapjadi	Herb	Geaniaceare	Root	Snake bite
28.	*Geum elatum* Wall.	Jungle hinglechu	Herb	Rosaceae	Whole plant	Quick healing of wounds and cuts
29.	*Grewia optiva* J. R. Bruman	Dhraman	Tree	Tiliaceae	Fruit, bark, leaves	Appetizer, increase milk production, fibres
30.	*Hypericum perforatum* L.	Suganjadi	Herb	Hypericaceae	Whole plant	Chronic inflammation of internal organs and gynaecological disorders
31.	*Juglans regia* L.	Achud	Tree	Juglandaceae	Bark, fruit, leaf	Cleaning teeth
32.	*Jurinea dolomiala* Boiss	Doop	Herb	Asteraceae	Root	Incense gout and rheumatism
33.	*Juniperus communis* L.	Bethar	Shrub	Cupressaceae	Fruit, root, needles	Joint pains flavouring gins liqueurs and cordials
34.	*Mallotus philippinensis* (Lam) Muell-Arg.	Dadu	Tree	Euphorbiaceae	Fruit	Red dye constipation, wounds, ulcers
35.	*Malva neglecta* Wall.	Laffa	Herb	Malvaceae	Whole plant	Astringent, laxative, inflammation
36.	*Meconopsis aculeata* Royle	Charuke gadi	Herb	Papaveraceae	Root	To make children healthy

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37.	*Melia azedarach* L.	Dhrankh	Tree	Meliaceae	Bark	Ascariasis, vaginal infection
38.	*Mentha Arvensis* L.	Puthnu	Herb	Lamiaceae	All ground above parts	Vomiting and increasing digestibility
39.	*Mentha lognifolia* (L.) Handson	Pufaklie	Herb	Lamiaceae	Leaf, stem	Killing lice and other insects, carminative
40.	*Olea ferruginea* Royle	Kau	Tree	Oleaceae	Whole plant	Cure pimples, anti periodic in fever and debility
41.	*Pinus roxburghii* Sargent	Chir	Tree	Pinaceae	Wood	Resin, perfumery industry insecticide
42.	*Pinus wallichiana* A. B. Jackson	Kail	Tree	Pinaceae	Wood	Resin which forms oleoresin and herpentine oil
43.	*Pistacia integerrima* Stewart Ex Brandis	Kankrya	Tree	Anarcadiaceae	Pod	Cough bronschitis asthma
44.	*Plantago lanceolata* L.	Musal	Herb	Plantaginaceae	Leaf, seed husk	cough diuretic antimicrobial, constipation
45.	*Plumbago zeylamica* L.	Pachas jadi	Herb	Plumbaginaceae	Root	Diarrhea/dysentery
46.	*Primula denticulate* Sm.	Chonk	Herb	Primulaceae	Leaf	Reappearance of hairs
47.	*Prunus armeniaca* L.	Cher	Tree	Rosaceae	Fruit	Excellent dresser
48.	*Punica granatum* L.	Daru	Small tree/ Shrub	Punicaceae	Fruit	Cure cough
49.	*Pyrus communids* L.	Bhagosha	Tree	Rosaceae	Fruit	Constipation appetizer
50.	*Pyrus malus* L.	Sau	Tree	Rosaceae	Fruit	Sour apple given to diabetic patients
51.	*Pyrus pashia* Buch Ham. ex D. Don	Kainth	Tree	Rosaceae	Fruit	Eye conductivities and diarrhea
52.	*Rheus austral* D. Don	Prambachalan	Herb	Polygonaceae	Root	Quick healing of wounds
53.	Rheum morcro fianum Royle	Prambachalan	Herb	Polygonaceae	Root	Purgative, dying woolen clothes
54.	*Rhododendron companulatum* D. Don.	Englu	Tree	Ericaceae	Leaf	Chromic rheumatism syphilis and scratica
55.	*Rubus ellipticus* Smith	Kanchu	Shrub	Rosaceae	Fruit	Increase digestibility
56.	*Rumex hastatus* D. Don.	Khatyami	Shrub	Polygonaceae	Leaf	Appetizer swelling of belly of animals
57.	*Rumex nepalensis* Spreng.	Hablu	Herb	Polygonaceae	Leaf	Excreting poison left inside body of animals after delivering offspring fever pneumonia of animals
58.	*Saussurea costus* (Fale)	Kuth	Herb	Asteraceae	Root	Joint pains
59.	*Skimmia laureola seib* et. Zucc ex Walp	Shangli	Shrub	Rutaceae	Leaf	incense at the time of worship kuldevas and devtas
60.	*Solanum surattense* Burn. F	Kantari	Shrub	Solanaceae	Whole plant	Seed are given to dogs to cure all diseases
61.	*Solena amplexiculis* Lam.	Bankakri	Creeper	Cucurbitaceae	Root, leaf and seed	Appetizer, carminative, purgative fevers of animals
62.	*Swertia petiolata* D. Don	Chirata	Herb	Gentianaceae	Wholeplant	Stomachache, laxative
63.	*Taxus baccata* L.	Patulu	Tree	Taxaceae	Leaf, bark	Asthma, bronchitis and cough
64.	*Thymus serphyllum* Linn.	Marchi	Herb	Lamiaceae	Whole plant	Common cold, stomach ailments, to correct eyesight
65.	*Urtica dioica* L.	Shader	Herb	Urticaceae	Root	Dysentery and diarrhea of animals
66.	*Valeriana jatamansi* Jones	Murmou	Herb	Valerianaceae	Whole plant	Hypertension and excess anger
67.	*Verbascum Thapsus* L.	Lavashlather	Herb	Surophulariaceae	Whole plant	Relieve respiratory tract irritation
68.	*Viola canescens* Wallich.	Bunafsha	Herb	Violaceae	Whole plant	expulsion of phlegm, cure sore throat

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medicinal plants that provides an incentive protect and maintain domestic and wild populations, their habitats and genetic diversify (Schippmann *et al.*, 2002).

During the course of study a number of myths and traditional beliefs were explored in the study area of Ramban forest division. Traditional knowledge of use of medicinal plants are passed-on from one generation to next as a family secret. Most of the shepherds and other people living on or near forests have belief that if they share their traditional knowledge regarding herbs they may lose their curative properties some people have belief that if a specific medicinal herb is uprooted on a specific day only then it's effect property is at its peak. Some people believe in myth that some specific medicinal herbs are uprooted after reciting of mantras only then they are effective in controlling the diseases.

During the course of survey, it has been found that tribes viz., gujjars and bakarwals, shepherds and few old people living in the upper reaches of the study area have a vast knowledge of usage of medicinal and aromatic plants. The information regarding traditional knowledge local name and parts used, purpose for which used and curative properties of the collected plant species have great significance. Traditional knowledge of the local communities in the study area may provide the scientific communities with the clues for screening medicinal plants as potential source for bioactive compounds that could result in the discovery of novel anti-microbial agents. The important endangered medicinal and aromatic plants in the study area are *Saussurea costus*, *Dioscorea deltioidea*, *Jurinea dolomiaea*, *Podophylum hexandrum*, *Rheum emodi* and *Skimmia laureola*. The unscientific extraction, overgrazing and unorganized trade are responsible for sharp decline of the herbal wealth of the area. It is therefore suggested that some immediate measures like banning of unscientific extraction and promotion of medicinal plants in their natural zones should be encourages saving the important species from extinction.

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Performance of Multipurpose Tree Species and Grasses under Different Soil Working Techniques on Degraded Lands of Himachal Pradesh

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Abstract: The present investigation on performance of MPT's and grasses under different soil working techniques revealed that continuous contour was the most suitable soil working technique for establishment of MPT's and grasses among three soil working techniques used i.e., continuous contour, small ridge ditch and pit planting. The survival percentage, plant height, collar diameter, above ground biomass, total biomass, and root weight, was found better in continuous contour in *Grewia optiva* and *Morus alba*. Continuous contour also proved to be most effective in relation to performance of grasses and resulted into higher survival (%), maximum number of tillers and maximum tiller length plant^{-1} for *Setaria sphacelata* and *Panicum maximum*.

Key Words: Multipurpose tree species, MPT's, soil working techniques, degraded lands

In the foothills of Western Himalaya, large areas are categorized as bouldery wastelands, which have been formed due to the deposition of huge amounts of coarse soil-forming material brought down by seasonal torrents originating in the higher reaches. Deforestation, inappropriate land use practices and road construction in the upper reaches lead to the displacement of soil, which moves down the slopes and is deposited in the foothills in the form of gravel bars, with coarser fractions spreading out over the original soil layers (Singh *et al.*, 2008). Increasing human population, livestock and improper landuse has been attributed to be a major causative factor of serious land degradation in India.

In the state of Himachal Pradesh, 17.6% of the geographical area is under permanent pasture or grazing lands. The livestock population of the state is three times the carrying capacity of grazing lands and this has resulted in the deterioration of the grass cover as well as valuable forest species. Due to population explosion and land hunger, even marginal land area have been increasingly brought under cultivation, leaving only highly degraded or poor areas for raising social forestry species (Anonymous, 2010). The biomass based economy of rural population calls for restoration of tree vegetation on degraded and poor areas in order to fulfill the fodder, fuelwood, small wood, minor forest produce needs of rural masses, besides providing benefits of protective/regulative functions and amelioration of the environment. The main constraints in the establishment of plant seedlings on degraded stress sites are poor soil depth, lack of moisture availability and rapid runoff rate. High intensity of soil working coupled with moisture conservation practices likely provide an answer to overcome these constraints towards successful establishment and subsequent performance of tree/crops aimed at greening sites/soil with useful broad leaved tree species. The basic aim of planting MPTS is to rehabilitate highly eroded areas, check soil and water losses and to improve the degraded lands as also to provide fuel wood, fodder and small timber to the farmers. It was, therefore, proposed to investigate the performance of two useful; tree species *Grewia optiva* Drummond and *Morus alba* Linn. along with two grass species under different intensities of soil working coupled with soil conservation techniques.

Grewia optiva Drummond belongs to family Tiliaceae is one of the most important fodder trees of North-western Himalayas. It is distributed throughout the sub-Himalayan tract, upto an altitude of 1800 m (Brandis, 1972). *Grewia optiva* Drummond excels all the other fodder in overall nutritive value and very well compares with cultivated leguminous fodders (Negi, 1986). It is sparingly found in forest area but mostly raised along agriculture fields (Singh, 1982) and heavily lopped for fodder. Similarly *Morus alba* Linn. is also important species of the region and belongs to the family Moraceae commonly known as shahtoot has been found promising because of its multiple uses. It provides a highly palatable nutritious leaf fodder and also used for rearing silk worms. The grass species viz. *Setaria sphacelata* var. *kazangula* and *Panicum maximum* (guinea grass) belonging to Poaceae family are considered good for intensively grazed permanent pastures in the humid

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subtropics as well as for hay production. These grasses possesses qualities like palatability, establishes easily from seed, persists under moderate grazing and are adapted to a wide range of soils.

MATERIAL AND METHODS

The experiment was laid out in the month of April 2013. The plantation of MPT's was done in the month of May-June and the grass tufts were planted in between the rows of trees in the month of July and data on various growth parameters of MPT's and grasses were recorded from June – October, 2013. The experiment was laid out in the field near University's Farmer Hostel, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan at an elevation of 1200 m above mean sea level facing south west aspect and lies at 30°51' N latitude and 76°11'E longitude. The climate of the site is sub-temperate to sub-tropical and semi-arid. Summer is moderately hot during May and June, winters severe during December and January. Frost occurrence is almost a daily feature during December and January. The average annual rainfall ranges from 1000-1100 mm, most of which is received during monsoon (July and August). Winter showers although common but usually mild.

Experimental details: Experimental field was prepared by worked out trenches for establishing continuous contour and small ridge-ditch treatments. Pit was dug directly without preparing the land. The plot was prepared to accommodate all the treatments for the MPT's. Uniform and healthy seedlings of *Grewia optiva* Drummond and *Morus alba* Linn (approx. same height) were transplanted in experimental field. Similarly, grass tufts were shifted from the grass nursery in the month of July and transplanted in the field between rows of MPT's. In all, three soil working techniques were applied as treatments for both MPT's and grasses, replicated sevenfold and worked out under Randomized Block Design for MPT's and RBD factorial for grasses.

Observations on growth parameters of MPT's were recorded throughout the experiment. Survival per cent of seedlings were recorded at the end of experiment. Plant height and collar diameter were recorded in the month of October. Three plants of each treatment were randomly taken for total above ground biomass measurement. The length of tap root of three plants per treatment was measured with the help of tape at the end of experiment. The length of primary and secondary roots (up to 2 mm in diameter) was determined with the help of measuring tape at the end of experiment. The samples of the roots were first air dried and then oven dried at 60 °C till constant weight. Numbers of leaves were recorded at the end of the experiment by manual counting. Numbers of branches were recorded by random selection of plants per treatment at the end of the experiment by manual counting. Observations on grass species were also recorded during October, 2013.

Statistical analysis: Data generated from present investigations were statistically analyzed as per the methods outlined by Gomez and Gomez (1984). Critical difference (CD) at 5% level of significance was used for testing the significant difference among the treatment means.

RESULTS AND DISCUSSION

Effect of different soil working techniques on survival and growth of *Grewia optiva* and *Morus alba*: The results obtained from experiment show that different soil working techniques had a non-significant influence on the survival per cent of *Grewia optiva* and *Morus alba* (Table 1). The survival per cent varies from 80.95- 100 per cent in *Grewia optiva* and 95.24-100 per cent in *Morus alba* under different soil working techniques. The survival percentage of *Grewia optiva* and *Morus alba* was recorded hundred per cent in continuous contour as compared to other two soil working

Table 1. Effect of different soil working techniques on survival (%), plant height (cm) and collar diameter (cm) of *Grewia optiva* and *Morus alba*

Soil working techniques	Survival (%)		Plant height (cm)		Collar diameter (cm)	
	Grewia optiva	*Morus alba*	*Grewia optiva*	*Morus alba*	*Grewia optiva*	*Morus alba*
Continuous trench	100.00 (10.00)	100.00 (10.00)	122.00	143	1.43	1.46
Ridge ditch trench	90.47 (9.50)	100.00 (10.00)	120.71	104	1.21	0.93
Pit	80.95 (8.90)	95.24 (9.47)	39.57	74	0.82	0.85
Mean	90.47 (9.50)	98.41 (9.91)	94.10	107	1.15	1.08
CD (0.05)	NS	NS	15.55	11	1.23	0.15

*Figure in parentheses are square root transformation values

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Table 2. Effect of different soil working techniques on no. of leaves, branches/plant and root length (cm) of *Grewia optiva* and *Morus alba*

Soil working techniques	*Grewia optiva*		*Morus alba*		*Grewia optiva*		*Morus alba*	
	No. of branches plant^{-1}	No. of leaves plant^{-1}	No. of branches plant^{-1}	No. of leaves plant^{-1}	Root length (cm)	Tap root length (cm)	Root length (cm)	Tap root length (cm)
Continuous trench	10.86	40.86	13.14	76.95	78.57	20.57	55.14	42.43
Ridge ditch trench	11.29	46.67	14.00	75.86	62.71	41.14	63.14	35.14
Pit	5.00	26.33	5.57	37.76	33.57	19.43	44.43	23.86
Mean	9.05	37.95	10.90	63.52	58.29	27.05	54.24	33.81
CD (0.05)	2.04	19.93	1.51	10.35	5.03	3.06	4.30	3.77

techniques. This might be due to high moisture conservation, less nutrients loss, etc. in continuous contour as compared to other soil working techniques. Various growth parameters viz., plant height, collar diameter, number of leaves, number of branches, root length, tap root length, above ground biomass, total plant biomass and root weight were recorded and presented in Tables 1-3.

The results obtained from experiments show that different soil working techniques had a significant effect on plant height in both the species (Table 1). Maximum plant height and collar diameter was recorded under continuous contour, whereas minimum plant height was recorded under pit planting technique in both the species. Numbers of branches per plant and number of leaves were significantly affected by different soil working techniques in both the species. In *Grewia optiva*, small ridgeditch recorded maximum number of branches per plant followed by continuous contour whereas, it was recorded minimum in pit planting. A similar trend was obtained in *Morus alba*. All the soil working techniques noticed to exert a significant influence on the root length and tap root length of *Grewia optiva* and *Morus alba* (Table 2). In case of *Grewia optiva*, continuous contour recorded maximum root length followed by small ridgeditch whereas, it was recorded minimum in pit planting. On the other hand, in *Morus alba* maximum root length was recorded in small ridge-ditch followed by continuous contour, whereas, it was recorded minimum in pit planting.

Similarly, different soil working techniques exercised significant influence on above ground (fresh and dry) biomass of both the species (Table 3). The above ground biomass of *Grewia optiva* and *Morus alba* was recorded maximum in continuous contour, whereas, it was recorded minimum in pit planting. The root weight (fresh) of *Grewia optiva* and *Morus alba* was recorded maximum in continuous contour followed by small ridge-ditch, whereas, it was recorded minimum in pit planting technique (Table 3). Similarly different soil working techniques were noticed to exert a significant influence on dry root weight of both the species. The root weight (dry) of *Grewia optiva* and *Morus alba* was recorded maximum in continuous contour followed by small ridge-ditch, whereas, it was recorded minimum in pit planting.

The reason for this may be the higher conservation of moisture and nutrients, less soil loss through runoff in continuous contour as compared to other soil working techniques. These observations were in accordance with the findings of Firdaus (1944), Chang (1960), and Bacvarov (1965).

Performance of grasses: The survival and growth parameters of *Panicum maximum* (Table 4) and *Setaria sphacelata* (Table 5) was recorded highest under continuous contour with *Grewia optiva* and *Morus alba* based silvipasture system. This might be due to less nutrient loss and high moisture conservation in gradoni. These results are also in conformity with the findings of Samra *et al.* (2000), while working on biomass production of trees and grasses in

Table 3. Effect of different soil working techniques on above and below ground biomass of *Grewia optiva* and *Morus alba*

Soil working techniques	Above ground biomass of *Grewia optiva* (gm)		Above ground biomass of *Morus alba* (gm)		Root weight of *Grewia optiva* (gm)		Root weight of *Morus alba* (gm)	
	Fresh	Dry	Fresh	Dry	Fresh	Dry	Fresh	Dry
Continuous trench	91.51	44.35	151.73	80.57	51.68	21.49	118.24	57.41
Ridge ditch trench	40.01	15.39	56.09	26.20	43.81	15.69	36.65	19.70
Pit	12.15	5.90	27.16	14.47	11.18	5.34	19.76	11.79
Mean	47.89	21.88	78.33	40.41	35.56	14.17	58.22	29.64
CD (0.05)	4.10	2.99	8.67	4.94	3.19	2.61	10.22	4.05

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Table 4. Effect of different soil working techniques on survival, tiller length and tiller number of *Panicum maximum* under *Grewia optiva* and *Morus alba* based silvi-pasture system

Soil working techniques	Survival (%)			Tiller length plant^{-1} (cm)			No. of tillers plant^{-1}		
	Grewia optiva	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean
Continuous trench	73.92 (59.97)	60.84 (51.45)	67.38 (55.71)	57.89	43.39	50.64	8.16	5.41	6.79
Ridge ditch trench	58.57 (50.06)	54.61 (47.65)	56.59 (48.85)	45.04	40.32	42.68	6.67	4.38	5.52
Pit	59.41 (50.95)	43.31 (41.00)	51.36 (45.80)	37.14	47.03	42.08	6.29	3.48	4.88
Mean	63.97 (53.54)	52.92 (46.70)		46.69	43.58		7.04	4.42	

*Figures in parentheses are arc sign transformation

CD (0.05)					
Techniques	5.97	6.28	1.00
Species	4.88	NS	0.82
Tech. x sp.	NS	8.89	1.42

Table 5. Effect of different soil working techniques on survival (%), tiller length and tiller number of *Setaria sphacelata* under *Grewia optiva* and *Morus alba* based silvi-pasture system

Soil working techniques	Survival (%)			Tiller length plant^{-1} (cm)			No. of tillers plant^{-1}		
	Grewia optiva	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean	*Grewia optiva*	*Morus alba*	Mean
Continuous trench	83.52 (8.69)	86.31 (8.86)	84.92 (8.77)	66.38	56.3	61.34	9.63	9.11	9.37
Ridge ditch trench	78.38 (9.10)	79.21 (9.28)	78.79 (9.19)	67.34	55.86	61.6	7.67	7.06	7.36
Pit	81.02 (8.96)	85.18 (9.21)	83.1 (9.08)	76.27	48.17	62.22	5.27	5.73	5.5
Mean	80.97 (8.92)	83.57 (9.12)		70.00	53.44		7.52	7.30	

*Figures in parentheses are square root transformation

CD (0.05)

Techniques	NS	NS	0.99
Species	NS	8.79	NS
Tech. x sp.	NS	NS	NS

silvipasture system on marginal lands of Doon Valley of north-west India. Similar findings were reported by Butt *et al.* (1992), Mustaque *et al.* (2009) and Sah *et al.* (2005).

From the results, it can be concluded that the different soil working techniques directly influenced the growth parameters of both trees and grass species. Continuous contour are better soil working technique for establishment of trees and grasses in slopy area for the establishment of silvipasture system.

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Sustaining Water Yield from Forest Catchment Through Vegetation Manipulation in Shivalik Himalayas

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Abstract: Vegetation manipulation was done in forest micro-watersheds in lower Shivalik region having dry mixed deciduous vegetation. The slope of watersheds varied from 32 % to 50 %. The watersheds were calibrated for two years followed by removal of 50 % crown of trees. Latter shrubs were removed in form of strips at different intensities viz. 30 %, 40 %, 50 % and complete removal. The average per cent runoff for two calibration years varied from 1.24 in MWS 31 to 10.74 in MWS 33. The runoff reduced over a period of time and in 2010 in varied from 0.21 per cent in MWS 31 to 1.66 per cent in MWS 30 of total rainfall. The removal of shrubs, in year 2011 in form of strips, induced the runoff and it varied from 1.3 to 8.39 per cent of the rainfall received. Before thinning the runoff received would not have been sufficient enough to provide one supplementary irrigation in all watersheds. However, the number of irrigation, after thinning, which can be provided, is about one in MWS 31 to about five irrigation in MWS 34 from three hectare forest watershed depending upon the intensity of thinning.

Key Words: Thinning, runoff, soil loss, vegetation, watershed

Himalayas are water towers of many important and perennial rivers of India. Over decades the upper catchment areas of the Himalayas had faced degradation and hence the water yield of many rivers and rivulets has decreased and many of them are now seasonal and ferocious during rainy season. Efforts are made from time to time through different schemes and agencies to afforest these catchments with the aim to conserve soil and water and to get water yield throughout the year. However, it had been observed in many studies that efforts of mechanical and vegetative measures reduced the runoff drastically. Dogra (2000) reported that imposing treatment of soil and water conservation reduced the runoff from 40.3 - 50.4 per cent to 0.4 - 5.8 per cent of the rainfall, within a span of four years in four different watersheds. Such efforts, though important from soil conservation point of view, have negative impact on the water flow in the rivers and rivulets in terms of quantity. The reduction in water yield was reported 14 to 29 % of rainfall in the watershed treated with mechanical and vegetative measures in Shivaliks (Hadda *et al.*, 2001). The major factor contributing this variation in runoff is the vegetation stratification, diversity and quantity. Samra *et al.* (1999) reported that replacement of 59 per cent of grassland by eucalyptus resulted in 16 % and 25.4 % reduction in water yield in first and second rotation of eucalyptus. The vegetation in lower strata of the forest particularly shrubs and grasses has a dominant role in variation in runoff and soil loss. Lower vegetation strata needs manipulation in such a way that we can augment the runoff but still keep the soil loss within the limits. Therefore, this study was initiated to develop technology for vegetation manipulation in micro-catchments through which sustained water yield is received from catchment and simultaneously soil loss is kept within tolerance limits.

MATERIALS AND METHODS

The study area lies in lower Shivalik Himalayan region of India with 30°45' N latitude and 70° 45' E longitude with an average altitude of 370 m above mean sea level. Five natural micro-hilly watersheds (MWS 30 to MWS 34) located within the research farm of CSWCRTI, Research Centre-Chandigarh were selected for the study. The area of micro-watersheds ranged from 0.8 ha to 4.7 ha (Table 1). Watershed number MWS – 33 was maintained as control under grass. The vegetation of the region falls under northern dry mixed deciduous types (Type 53/C2) typical natural mixed deciduous forest. The soil texture varies from sandy loam to loamy sand. Available carbon content ranged from 1.06 to 2.39 %. Steady state infiltration rates gradually decreases from upper to lower reaches. Mean steady state infiltration rate varied from 2.37cm hr^{-1} to 8.79 cm hr^{-1} in different watersheds in different reaches (Table 1).

The watersheds were under different treatments since 1970's and later on were maintained as natural forests. In the year 2005, all the five watersheds were calibrated for two years (2005 and 2006) with an objective of manipulating the vegetation of the watersheds for hydrological studies. In post calibration years (2007-2009), fifty per cent crown of each tree was removed from lower, middle and upper part of each watershed in 2007, 2008 and 2009, respectively,

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Table 1. Characteristics of different watersheds

Watershed characteristics	MWS30	MWS31	MWS32	MWS33	MWS34
Area (ha)	4.5	2.0	4.7	0.8	1.7
Perimeter (m)	980	600	940	430	580
Length of main channel (m)	450	255	420	190	240
Relief (m)	105.9	69.8	102.2	57.9	64.9
Overland slope (%)	44.9	32.1	48.9	50.4	50.6
Form factor	0.22	0.31	0.27	0.22	0.29
Drainage density (mm^{-2})	0.032	0.022	0.036	0.05	0.048
Compactness coefficient	1.29	1.19	1.21	1.35	1.24
Time of concentration (min)	3.76	2.29	3.51	1.75	2.20

which allowed the light to penetrate to the ground floor and this encouraged the lower strata vegetation. Simultaneously *Lantana camara*, which had invaded the watershed was also removed every year in all the micro-watersheds. Vegetation survey was also done regularly in the watersheds. In the year 2011, shrubs were removed with the objective of inducing the runoff while simultaneously keeping the soil loss below the tolerance limits. The shrubs were removed in strips at different intensities ranging from about 30 per cent to complete removal of shrubs (Table 2). To achieve these thinning intensity, each watershed was divided into lower, middle and upper reaches (Fig. 1). The removal of shrubs in strips as per the thinning intensity was done on upper side of the lower reach as well as middle reach and lower side of the upper reach (as shown by shaded areas). Runoff and soil loss were measured every year by gauging watersheds through 0.6 m deep 2:1 broad crested triangular weirs. The runoff was measured by water level recorders.

RESULTS AND DISCUSSION

Runoff observed during calibration period and thereafter is given in table 3. It was found that during calibration years 2005 and 2006, the rainfall was low (490 and 543 mm), respectively as compared to post calibration period. The runoff in the watersheds varied from 5 mm in MWS 31 to 63.3 mm in MWS 30 in the year 2005 and from 7.7 mm in MWS 31 to 47.7 mm in MWS 33. The average per cent runoff for two years during calibration period varied from 1.24 in MWS 31 to 10.74 in MWS 33.

In the vegetation survey in all the watersheds after removal of vegetation, it was found that the understorey vegetation has increased. Indigenous species like *Justicia adhatoda*, *Murraya koenigii*, *Carissa opaque*, etc., which are light demanders got encouraged over a period of time (Panwar *et al.*, 2011 and Sharma *et al.*, 2012). As a result of good diversity of the lower vegetation strata, the runoff in all the watersheds reduced. In 2007, the minimum runoff was 0.3 per cent in MWS 31 followed by 1.20 per cent in MWS 30, 1.23 per cent in MWS 33, 1.62 per cent in MWS 34 and highest 3.06 per cent in MWS 32. In 2010, the runoff further decreased in all the watersheds except MWS 30, where it slightly increased. The runoff varied from 0.21 per cent in MWS 31 to 1.66 per cent in MWS 30 (Table 3).

In 2012, it was found that after removal of the shrubs, the runoff increased. Runoff varied from 1.3 to 8.39 per cent of the rainfall received. It was highest in MWS 30 followed by MWS 33, MWS 34, MWS 31 and least in MWS 31 (Table 3). The per cent increase in the runoff after removal of shrubs was 2.7 per cent in MWS 30, followed by MWS -32 (4.4 %), MWS – 33 (6 .0 %), MWS – 31 (5.2 %) and maximum runoff was in MWS – 34 (8.02 %). The mean runoff per cent received between 2007 to 2011 was compared with the post vegetation manipulation (Fig. 2). It was found that the runoff was higher in all the watersheds post treatment compared to pre-treatment period. In pre-treatment period, the runoff varied from about 1 per cent to just less than 4 per cent, whereas, in post-treatment, the runoff increased and varied from just above 1.5 per cent to more than 8.0 per cent.

Soil loss was compared between pre and post treatment. It was found that soil loss in 2007 ranged from 50 kg ha^{-1} in MWS 31 to 5520 kg ha^{-1} in MWS 34, whereas, it ranged from 30 kg ha^{-1} in MWS 31 to 2770 kg ha^{-1} in MWS 30 in 2012 (Table 4). Mean soil loss between 2007 to 2011 in different watersheds were compared with the soil loss in 2012 (Fig. 3). It was found that mean soil loss was much higher or equal to in pre-treatment period except for MWS 33 where soil loss was higher in post treatment phase.

The amount of runoff (mm) obtained before and after thinning (Table 3) was converted to cubic meter to find out the benefits, which can be reaped by a user/ manager/ forester for supplemental irrigation. Since area of each watershed was different, therefore, the runoff obtained in each watershed was converted to runoff (cu m) per hectare (Table 5). It was found that thinning intensity had direct relation with the amount of runoff, which can be induced per

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Table 2. Thinning intensity in different watershed

Watersheds	MWS 30	MWS 31	MWS 32	MWS 33 (Control)	MWS 34
Upper reach	30	40	50	No intervention (grass watershed)	Complete removal of under storey from all reaches
Middle reach	50	50	50		
Lower reach	20	30	50		
% removal	33	40	50		100 %

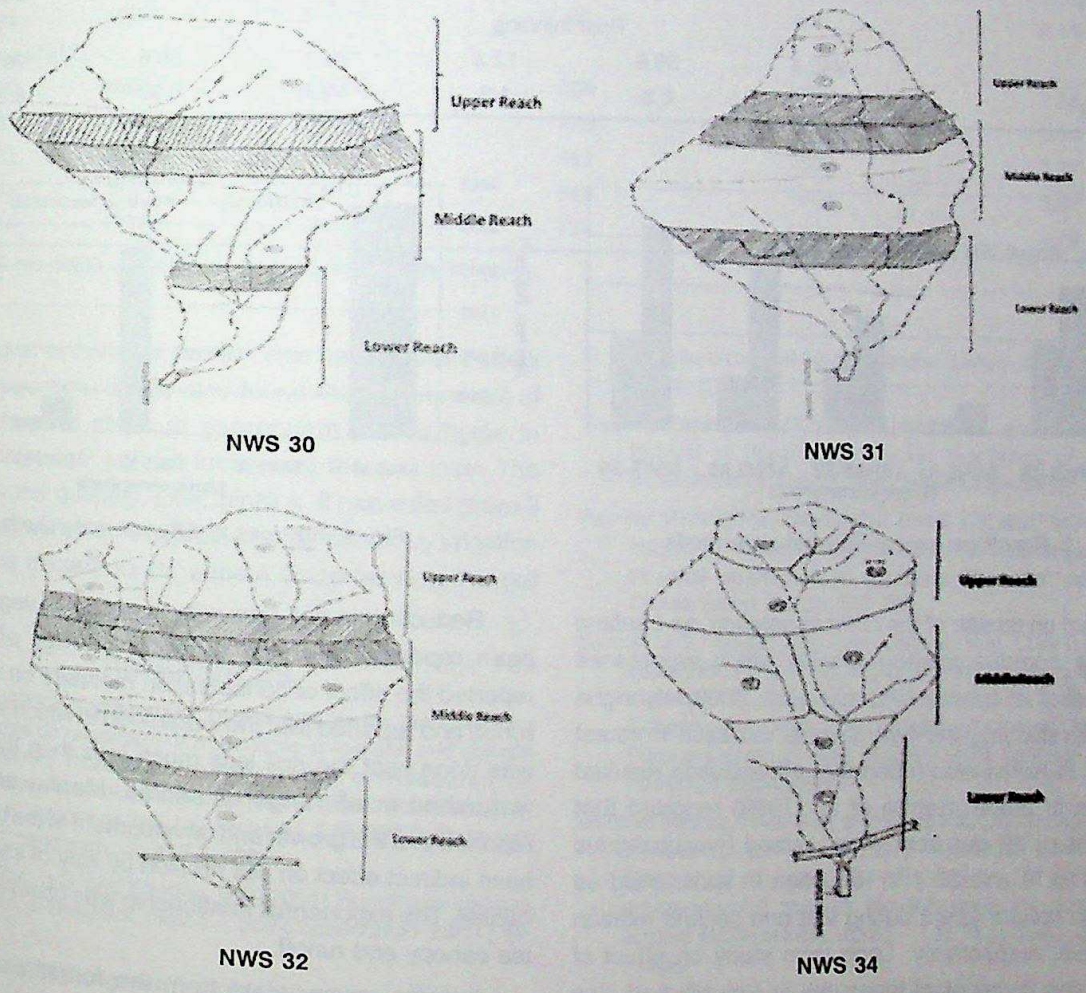

Fig. 1. Location of vegetation removal in strips (Maps not to the scale)

hectare. Generally one supplemental/life saving irrigation to wheat crop in one hectare require 500 cu m (if 5 cm depth) water. If all the watersheds were of three hectare, the water which can be harvested/received before thinning was 57 to 444 m^3, whereas, it would be 369 to 2382 m^3 after thinning. Before thinning, the runoff received would not have been sufficient enough to provide one supplementary irrigation of 5 cm depth in one hectare of wheat crop in all watersheds. However, the area which can be irrigated, after thinning, ranged from 0.738 hectare in MWS 31 to about four and a half hectare in MWS 34 (Table 5). Thus, availability of sufficient water will certainly improve the production of the crop.

It was found in the study that after removal of 50 % of tree canopy, the runoff decreased during 2007 and 2010. This is because of the fact that removal of tree canopy resulted in penetration of sun light to the ground surface as a result of which many shrubs started growing profusely leading to dense vegetation which led to decrease in the runoff. In addition to 50 per cent removal of tree canopy, *Lantana camara* was also removed in all the watersheds throughout the experimental years. This activity also had a

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Table 3. Rainfall and per cent runoff in different watersheds

Watershed characteristics	Rainfall (mm)	MWS30	MWS31	MWS32	MWS33	MWS34
2005	490.3	36.8	5.1	18.7	63.3	26.2
2006	543.1	10.5	7.7	13.8	47.7	16.4
Total (mm)	1033.4	47.3	12.8	32.5	111	42.6
Runoff (%)		4.58	1.24	3.14	10.74	4.12
2007	708.6	8.50	2.10	21.70	8.70	11.50
Runoff (%)		1.20	0.30	3.06	1.23	1.62
2010	893	14.80	1.90	8.00	8.80	8.30
Runoff (%)		1.66	0.21	0.90	0.99	0.93
		Post thinning				
2012	945.8	59.6	12.3	46.1	65.6	79.4
Runoff (%)		6.3	1.3	4.87	6.93	8.39

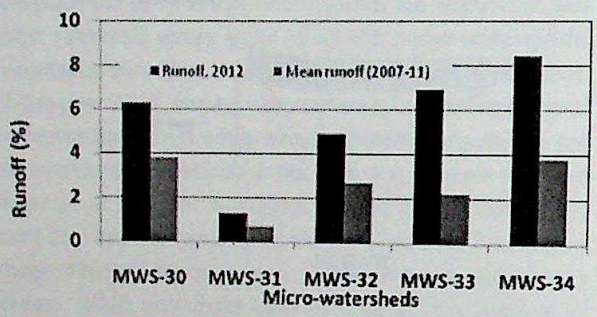

Fig. 2. Runoff per cent in different watersheds

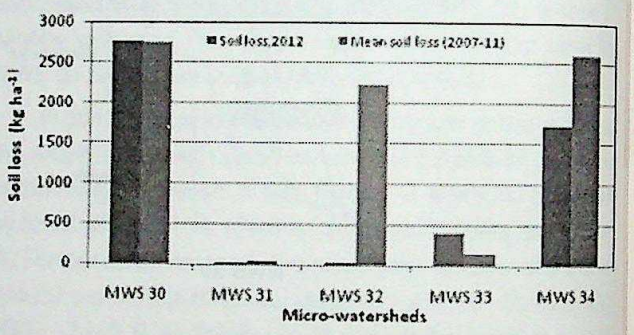

Fig. 3. Soil loss in different watersheds

positive effect on growth of the other vegetation, as *Lantana camara* is a vigorous growing species which suppresses the growth of other species (Sharma *et al.*, 2009). Kyongha (1998) while studying the hydrological variation in forest catchments in Korea also found that afforestation resulted in reduction in runoff. Samra *et al.* (1999) reported that replacement of 59 per cent of grassland by eucalyptus resulted in 16 % and 25.4 % reduction in water yield as compared to natural forest during first and second rotation of eucalyptus, respectively. Long term study on effect of vegetative and mechanical measures in Shivalik had also revealed that the runoff can be harvested to a range of only 10 – 20 per cent of the total rainfall (Tiwari *et al.*, 2012).

Table 4. Soil loss during pre and post treatment

Watershed (Landuse)	Soil loss (kg ha^{-1})	
	2007	2012
MWS 30	360	2770*
MWS 31	50	30
MWS 32	140	40
MWS 33	440	420
MWS 34	5520	1740

*During 2012 landslide occurred in MWS 30, which resulted in more soil loss

Reduction in soil loss with increase in vegetation had been reported by many authors. Panwar *et al.* (2012) reported the effect of conservation measure on reduction of runoff and reported that the watershed in which afforestation was done kept the soil loss much less than the untreated watershed in all range of rainfall. Madhu *et al.* (2011) reported that the growth and development of tea bush canopy have indirect effect on soil erosion by way of interception of rainfall. The exponential relationship was observed between tea canopy and runoff.

Inducing water yield from the forest watersheds is important for providing drinking and irrigation water and for other uses for downstream population. Since shrubs had more biomass and hence intercept more water therefore, removal of shrubs increased the water yield. Though removal of shrubs increased the runoff as well, but soil loss reduced. It was because of the fact that the shrubs were not removed from the lower part of the watershed which acted as a buffer and hence did not allowed the soil particle to move away from the area.

The study reveals an effective technique for optimizing runoff and reducing soil loss by just removal of the canopy by pruning of the trees so that the natural vegetation of the region grows profusely due to availability of light to ground

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Table 5. Amount of water harvested and its utilization

Water Shed	Area (m^2)	Water received through runoff (cum)	Water received through runoff per ha (cum)	Water received from 3 hectare (cum)	Area of wheat which can be given one supplemental irrigation (ha)*
Before thinning (2010)					
MWS -30	45000	666.0	148	444	0.88
MWS -31	20000	38.0	19	57	0.11
MWS -32	47000	376.0	80	240	0.48
MWS -33	8000	70.4	88	264	0.53
MWS -34	17000	141.1	83	249	0.49
After thinning (2012)					
MWS -30	45000	2682.0	596	1788	3.58
MWS -31	20000	246.0	123	369	0.74
MWS -32	47000	2166.7	461	1383	2.77
MWS -33	8000	524.8	656	1968	3.94
MWS -34	17000	1349.8	794	2382	4.76

*assuming 5 cm depth of water for one supplementary irrigation

flora. Removal of *Lantana camara* also have positive effect on runoff reduction. It was also found that the removal of shrubs in form of strips at appropriate places helps in inducing the runoff without increasing the soil loss. The increased water quantity, after thinning, if harvested (from 3 hectare land) will be able to provide supplementary irrigation to about five hectare lands without compromising the soil loss.

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Biotechnological Interventions for Improvement of Forest Trees

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Abstract: Biotechnology provides important tools for the sustainable development of agriculture, fisheries and forestry and can be of significant help in meeting the food needs of a growing urbanized population. Potential applications of biotechnology in tree improvement fall into three main areas viz., genetic markers that help researchers identify trees with desirable genes, new vegetative reproduction methods that aid in the production of improved planting stock and genetic engineering that can provide useful information about cell biology and function and in the long term help researchers produce trees with novel traits. Molecular markers specially RAPD are being applied to a greater extent in forest trees to study genetic diversity and contribute about 25 per cent of the total molecular markers used in forest biotech activities (FAO, 2004b). Micro-propagation by rooted cutting is commonly used in more than 20 species of commercial importance, the majority of which the angiosperms. In broad-leaved species, vegetative propagation of GM material is likely to use a combination of micro-propagation and rooted stem cuttings, at least in the beginning. The current trend in MAS is towards the selection of superior alleles in candidate genes directly controlling phenotypic variation in traits of interest. Introducing targeted genes into the genome of a forest tree is a way to obtain GM plants. It is also a basic research tool for better understanding of gene functioning in woody plants. The impact of biotechnology on genetic studies has allowed the use of cutting-edge methodologies in forest tree species in spite of their poor domestication compared with food crop.

Key Words: Genetic markers, GM trees, micro-propagation, genome mapping

Biotechnology research and application in forestry is truly global in scope with activities identified in 76 countries. Significant activities occurred in developed countries (68%), with United States (14%), France (9%) and Canada (8%) the most active participants represented in the data set (percentages are of total citations of main biotechnology activities). India (9%) and China (6%) were far away from the developing countries and countries in transition. Regionally, forest biotechnology activities were numerous in Europe (39%), Asia (24%) and North America (23%), and least numerous in Oceania (6%), South America (5%), Africa (3%) and the Near East (less than one per cent) (White *et al.*, 2007). While forest biotechnology research and application has spread to at least 140 genera, majority of which (62%) has been focused on only six genera (*Pinus, Eucalyptus, Picea, Populus, Quercus* and *Acacia*, in descending order of activity) and are represented in Fig. 1.

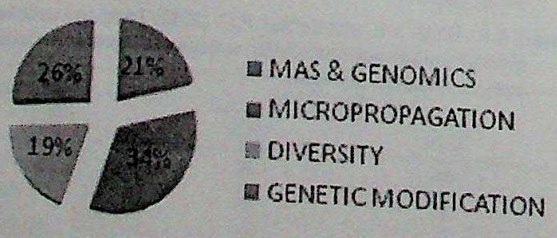

Fig. 1. Proportion of biotechnology activities in forestry sector

Potential applications of biotechnology in tree improvement fall into three main areas (Yanchuk, 2001) viz., (i) genetic markers that help researchers identify trees with desirable genes, (ii) new vegetative reproduction methods that aid in the production of improved planting stock and (iii) genetic engineering (MMG's) that can provide useful information about cell biology and function and finally may help researchers produce trees with novel traits. The forestry sector appears to have rapidly adopted markers developed for agricultural crops. Isozymes and random amplified polymorphic DNA's (RAPD's) have been widely used for genetic diversity description although the present trend seems to favour microsatellites (nuclear and chloroplast) and amplified fragment length polymorphisms (AFLP's). Driven by research on genomics, expressed genome banks (EST's [expressed sequence tags]) are being widely developed. The majority of the work reported is still mainly at the experimental stage in the laboratory however, field trials are mainly geared to support laboratory research (Srinidhi and Chauhan, 2007). Commercial applications of micro-propagation are, however, generating increasing interest. The potential is huge although, up to now, only several thousand hectares seem to have been established globally using micro-propagated material.

Molecular Markers

Recent approach to forest genetics is to develop appropriate molecular markers or system of markers to examine the diversity, genetic differentiation and gene flow in fragmented populations. Information emerging from such

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studies is useful in formulating proper conservation strategies. Molecular markers have significant value in breeding programmes to characterize and evaluate genetic diversity in germplasm, population etc. Strauss *et al.* (1992) distinguished between two classes of molecular marker viz. molecular genetic markers (those derived from direct analysis of polymorphism in DNA sequences), and biochemical markers (those derived from study of the chemical products of gene expression). Molecular markers can be either dominant (only the dominant allele is expressed if both parents are genetically different at a given locus) or codominant (the genotypes of both parents are quantifiable at a locus). Dominant markers (amplified fragment length polymorphisms [AFLP's], randomly amplified polymorphic DNA's [RAPD's]) require larger sample sizes for statistical analysis than codominant markers (isoenzymes, microsatellites/simple sequence repeats [SSR's], restricted fragment length polymorphisms [RFLP's], sequence-tagged sites [STSs], expressed sequence tags [EST's], single nucleotide polymorphisms [SNP's] (White *et al.*, 2007).

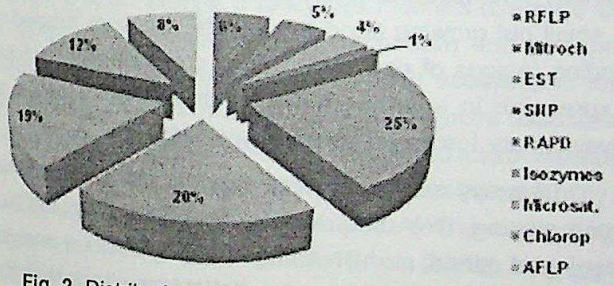

Fig. 2. Distribution of molecular markers used in forest biotechnology

Molecular markers specially RAPD are being applied to a greater extent in forest trees to study genetic diversity and contributes about 25% of the total molecular markers used in forest biotechnology (FAO, 2004a). Molecular tools have been widely used to measure gene flow and genetic diversity of natural and artificial populations of forest trees and associated species, and the impacts of anthropogenic disturbance on their evolutionary potential (Ritland and Ritland, 2000; Yanchuk, 2001). Use of molecular markers provides an objective assessment of genetic diversity in a plant species and enables unequivocal identification of elite genotypes.

Genetic Markers

A genetic marker is a measurable character that can detect variation in either a protein or DNA sequence. A difference, whether phenotypic or genotypic, may act as a genetic marker if it identifies characteristics of an individual's genotype and/or phenotype, and if its inheritance can be followed through different generations. A genetic trait may not have necessarily observable consequences on an individual's performance. Sometimes, however, this trait may be linked to, or correlated with, other traits that are more difficult to measure and do affect the individual's performance. In such cases, these unobservable genetic traits may be used as genetic markers for the linked traits because they indirectly indicate the presence of the characteristics of interest.

Traditionally, diversity within and between populations was determined by assessing differences in morphology known as morphological markers. These measures have the advantage of being readily available, do not require sophisticated equipment and are the direct measure of phenotype, thus they are available for immediate use, an important attribute. However, morphological determinations need to be taken by an expert in the species, which are subject to changes due to environmental factors and may vary at different developmental stages and their number is limited. Albino needles, dwarfing and many other aberrations, resultant mutations were observed as morphological markers but due to rare occurrence, highly detrimental and often lethal have limited application to trees (Mandal and Gibson, 1998; White *et al.*, 2007).

To overcome the limitations of morphological traits, other markers have been developed both at the protein level (phenotype) and the DNA level (genotype). Protein markers are usually named 'biochemical markers' but, more and more; they are mistakenly considered as a common class under the so-called 'molecular markers'. Most of the work under forestry was earlier focused on biochemistry (e.g. terpenoids especially mono-terpenes in pines), progressed to biosynthetic constitutive or induced protein expression (isoenzymes) and is now utilizing DNA-based tools (e.g. microsatellites, quantitative trait loci [QTLs]) since the advent of PCR (polymerase chain reaction) technology. However, protein markers are also limited by being influenced by the environment and changes at different developmental stages. Even so, isozymes are a robust complement to the simple morphometric analysis of variation. Another type of protein based genetic markers utilizes 2-D PAGE technology mostly utilized for extensive linkage mapping in *Pinus pinaster* are more difficult than Isozymes and often dominant in expression (Plomion *et al.*, 1997).

For forest tree species, isozymes have been widely used for the assessment of among and within population variation e.g. for *Abies alba, Larix decidua, Picea abies, Pinus cembra, P. halepensis, P. leucodermis, P. nigra, P. pumila, P. sibirica, P. sylvestris, Castanea sativa, Fagus sylvatica, Ficus carica, Quercus ilex, Quercus petraea, Quercus robur* (Muller-

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Strack *et al.*, 1992), *Alseis blackiana, Picea glauca, Robinia pseudoacacia, Pinus resinosa, P. torreyana, Populus balsamea, Acer saccharum* (Hamrick *et al.* 1992). *Pinus banksiana, P. contorta, P. monticola, Picea mariana, P. glauca, P. sitchensis, Pseudotsuga menziesii and Thuja plicata* (Neale and Williams, 1991).

Mapping, Marker-Assisted Selection and Genomics (MMG)

During 1990s significant biotechnology activity centred on the development of molecular markers, test populations, genetic linkage maps, and statistical means of identifying quantitative trait loci (QTLs). QTLs represent statistical associations between markers and genes that control some proportion of the genetic and phenotypic variation of a quantitative trait (generally less than 10% per QTL). QTLs have several potential applications including (i) genetic dissection of complex quantitative traits, (ii) providing the basis for MAS, and (iii) providing guidance for selection and prioritization of candidate genes. Linkage and QTL maps have been created for over two dozen tree species and though more maps are likely to appear, most current efforts appear to focus on increasing the density and type of markers located on these maps. The current trend in MAS is towards the selection of superior alleles in candidate genes directly controlling phenotypic variation in traits of interest. This approach, termed association genetics, differs in application from traditional QTL studies primarily in the form of the test population being studied. The recent completion of a whole-genome sequence for *Populus* has laid the foundation for reaching this goal for a model species, and efforts follow to replicate this deed in *Eucalyptus*, though progress is slower. Public and private EST libraries for conifers now exceed one million entries. The immediate application of genomics includes identification of candidate genes for association studies and targets for genetic modification. Also, comparative studies of EST's from different trees have revealed the tremendous similarity among taxa of conifers, and raise hope that what is learned from one species will benefit many others.

MMG activities are conducted globally, but are concentrated in Europe (43%) and North America (34%). About 40 genera have been studied but only four genera dominate the MMG landscape (*Pinus, Populus, Eucalyptus* and *Picea).* Methodological approaches to MMG studies heavily favour gene discovery, functional genomics and candidate gene identification (65% of total studies), while linkage and QTL mapping account for 31 per cent of activities. Proteomics activities are modest (2%). Where identified, MMG studies have targeted primarily genes controlling wood property traits (57%) and resistance to abiotic (20%) and biotic (4%) stresses. Growth rate (6%), genetic diversity (8%) and flowering (5%) make up the remaining major categories.

Genetic Diversity

Most studies targeting genetic diversity appear to be addressing and validating population genetic models or providing baseline data for the elaboration of conservation strategies. However, the application of these data for conservation purposes at the operational level is generally not obvious in the literature. Marker applications for fingerprinting and paternity analysis have found considerable utility in both basic science and commercial applications. Studies on paternity analysis of commercial willow hybrids (Choudhary *et al.,* 2013), genetic diversity characterization based on RAPD and microsatellite (Singh *et al.*, 2013) with gradually increasing use of nuclear and cytoplasmic microsatellites are the scope of studies. Virtually all these markers are considered neutral (not related to selection pressure) and may not be ideal for understanding genetic patterns influenced by evolutionary forces. There is a small but growing trend to use SNP markers located in coding regions of candidate genes controlling phenotypic expression in adaptive traits to study the influence of evolutionary forces on allele frequencies.

In forestry sector range of services being offered like gene cloning, DNA sequencing, molecular mapping and tagging of genes, and DNA fingerprinting besides analysis of genetic diversity. The use of DNA markers that are insensitive to environmental factors helps breeders screen individual plants at the seedling stage. As the cost of molecular marking is dependent on the nature of markers used, the type of material being processed, and the volume of work, the whole protocol prove out to be cost-effective (Lakshmikumaran, 2003). Molecular markers potential applications in forest tree included use of amplified fragment length polymorphism (AFLP) and SCAR (sequence-characterized amplified region) molecular markers to determine the incidence of 2n pollen (unreduced pollen) in *Populus tomentosa* (Zhang *et al.*, 2007), cpDNA to detect introgression in populations of *Quercus alba* from other oak species (Whittemore and Schaal, 1991), mtDNA RFLP to study introgression between *Picea sitchensis and P glauca* (Sutton *et al.*, 1991), RFLP's for studying the taxonomic relationships in *Eucalyptus* at various levels (Maunders, 1992), determining genotype data for biparentally (ISSR's) and maternally inherited (cpDNA PCR-RFLP's) molecular markers for 26 Swiss populations of *S. torminalis* (Angelone *et al.*, 2007), determining natural introgressive hybridization

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through analysis of nine highly polymorphic microsatellite (nuSSR) loci in three mixed oak populations (Valbuena *et al.*, 2007), Identification between *Prosopis juliflora* and *P. pallid.* (Landeras *et al.*, 2006), developing molecular databases with STS and EST DNA markers for discrimination of provenance regions of Norway spruce (Pucko *et al.*, 2005), using orthologous expressed sequence tag polymorphism (ESTP) and restriction fragment length polymorphism (RFLP) markers for identifying ten homologous linkage groups in loblolly pine (*Pinus taeda* L.) and Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco) (Krutovsky *et al.*, 2004), construction of expressed sequence tag (EST) libraries and the resequencing of EST-derived unigenes for a diverse array of forest tree species (http://dendrome.ucdavis.edu/cmap/) (Eckert *et al.*, 2009), mapping of genetic markers based upon expressed sequence tag polymorphisms (ESTPs) in loblolly pine (*Pinus taeda* L.) with primers designed from sequenced cDNA's, (Temesgen *et al.*, 2001), AFLP, SSR, and SNP for construction of a highly informative genetic map of *P. nigra* (Gaudet *et al.*, 2007), genetic linkage map of European chestnut (*Castanea sativa* Mill.) based on 311 RAPD's, 65 ISSR's, 5 isozymes markers (Casasoli *et al.*, 2001), conservation, sustainable use and genetic enhancement of bio-resources in fragile ecosystems for twenty-four species of mangroves and mangrove associate (Raghavan and Parida, 2006) and RAPD and micro-satellite markers to detect and maximize the genetic variability, identifying crossings favourable to a tree breeding programme in willows (Choudhary *et al.*, 2013), aiming at multiple use of markers in forest tree species.

Micro-propagation

Tree species can be micro-propagated by micro-cuttings or by somatic embryogenesis. Micro-propagation is used to create large numbers of individual clones or genotypes. Because vegetative propagation bypasses the genetic mixing associated with sexual reproduction, it represents an ideal way to deliver genetic gain: select individuals are replicated precisely. Micro-propagation by rooted cutting is commonly used in more than 20 species of commercial importance, the majority of which are angiosperms. Conifers are less easily rooted than angiosperms, though modest programmes for several genera exist. Organogenesis, or the creation of plantlets from tissues such as cotyledons, has largely fallen out of favour in forestry operations and is used infrequently. Germplasm and protocols are likely to be available for large-scale deployment for many of forest tree species like *Anogeissus* in India (Saxena and Dhawan, 2001); *Acacia mangium* and *A. mangium* × *A. auriculiformis* in Malaysia (Galiana *et al.*, 2003), *Pinus* in Canada and New Zealand (Lelu and Thompson, 2000) *Eucalyptus* in Australia (Watt *et al.*, 2003). It seems that cuttings are likely to dominate propagation in angiosperms in developing countries while somatic embryos will dominate in conifer propagation in developed countries. The majority of GM trees is likely to be used in the form of clonal materials and will need to be vegetatively propagated. In the case of conifers, somatic embryogenesis, especially when derived from a single cell, seems the most suitable regeneration and propagation technique. However, with the increased use of hybrids or triploids, the occurrence of somaclonal variation may increase (Dave *et al.*, 2001) true-to-typeness, particularly, may remain a problem for certain genotypes, and efforts are still needed for optimizing this technique to make it more reliable, especially when using mature selected genotypes.

Genetic Modification (GM) in Trees

Populus was the first tree to be genetically modified (1986) and is by far the most commonly studied tree genus for genetic modification purposes today (47% of activities). Since then, the genus has become a model for genetic modification and related tree biotechnology studies. The first attempt to genetically modify a conifer (*Larix*) was reported in 1991. Genetic modification activities in forestry are taking place in at least 35 countries, 16 of which host some form of experimental field trials. These field trials are generally very small and typically of short duration and are destroyed before seed bearing occurs. In the remaining 15 countries, experimentation is restricted to laboratories or greenhouses (Chaix and Monteuuis, 2004). To date, only China has reported the establishment of approved, commercial plantations of GM trees. Nearly two-thirds of the 520 reported genetic modification activities in forestry occur in North America (48%) and Europe (32%). Asia follows with 14 per cent of reported activities, Oceania with 5 per cent, South America with one per cent and Africa with less than one percent (FAO, 2004a).

Introducing targeted genes into the genome of a forest tree is a way to obtain GM plants. It is also a basic research tool for a better understanding of gene functioning in woody plants. This is no doubt a function of ease with which some genotypes of the genus can be transformed and vegetatively propagated for experimental purposes. As per FAO (2001), *Pinus* (19%), *Eucalyptus* (7%), *Liquidambar* (5%) and *Picea* (5%) make up the majority of the remaining experimental studies. Field trials of GM trees are restricted largely to four top genera (*Populus*, 51%; *Pinus*, 25%; *Liquidambar*, 11% and *Eucalyptus*, 7%).

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Introduction of a mutated version of the gene encoding the enzyme target for various herbicides: glyphosate for *Populus alba* x *P. grandidentata, P. trichocarpa* x *P. deltoides, Eucalyptus grandis, Larix decidua* and *Pinus radiata* (the herbicide blocks the synthesis of tryptophan, tyrosine and phenylalanine), or chlorosulfuron for *Populus tremula* and *Pinus radiata* (the herbicide blocks the synthesis of leucine, isoleucine and valine) was achieved. Moreover, introducing a microbial gene encoding an enzyme for the detoxification of the herbicide, and has been applied to *Populus alba, P. alba* x *P. tremula, P. tremula* x *P. alba, P. trichocarpa* x *P. deltoides* and *Eucalyptus camaldulensis* and *Pinus radiata* and *Picea abies* (Bishop-Hurley *et al.*, 2001). Use of microprojectiles to insert a gene encoding an endotoxin which binds to the receptors in the intestine of Lepidoptera, Coleoptera and Diptera, lysing the organ and killing the insect was done in *Populus alba* x *P. grandidentata, P. tremula* x *P. tremuloides* and *Picea glauca*. GM *Populus* trees and *Pinus radiata* expressing the *Bacillus thuringiensis* endotoxin '*Bt*' have been obtained. Potato gene *pin2*, a protease inhibitor was introduced into *P. alba* x *P. grandidentata* through *A. tumefaciens* (Klopfenstein *et al.*, 1991), and the gene of a rice protease inhibitor introduced into *P. tremula* x *P. tremuloides* (Heuchelin *et al.*, 1997). Simultaneous modification of two genes for enhanced resistance to insects was achieved in *Liquidambar styraciflua*, combining a peroxidase anionic enzyme gene involved in cell growth and wall development with a '*Bt*' gene (Sullivan and Lagrimini, 1993).

Genetic transformation to modify lignin characteristics is a key research feature on species used in the paper industry. The aim is to regulate the activity of key enzymes involved in the lignin biosynthesis pathway (Li *et al.*, 2003). Active on-going research targets the effects of lignin biosynthesis in *Populus* on soil carbon transformation and its storage. Researchers have developed techniques of tissue culture and genetic transformation for many tree species such as Poplar, Birch, Eucalypts, Larch, Wallnut, Apple and Citrus etc (Chaix and Monteuuis, 2004). Also for production of sterile trees and to prevent possible dispersal of transgenic pollen in the environment, an approach based on genetic ablation has been tested on poplar (Skinner *et al.*, 2000). Other approaches, based on the suppression of key flowering genes, are being tested.

Constraints to Genetic Modification in Trees

Environmentalists are concerned about potential negative impacts of genetic engineering of trees. Among major concerns includes escaping of novel genetic material into wild relatives, impacts of inserted pesticidal properties on forest food webs and ecosystem processes, repercussions of EST's developing resistance to pesticidal properties, enhanced weediness of the transgenic organism or its relatives in natural systems, impacts of altered lignin content on forest food webs and ecosystems and negative environmental impacts from application of technologies intended to manage the GE organism including induced sterility and increased use of herbicides (Faith and Rachel, 2001).

Future Perspective

Unlike work carried out on crop or farm animal species, the domestication of forest trees is, with few exceptions. However, within a few decades, knowledge transfer from agriculture to forestry has been so fast that genetic information of a few tree genera, such as poplar (*Populus*), pine (*Pinus*) and *Eucalyptus*, is important, in terms of complexity and quality. Expected gains for tree breeders include new genetic pools and significant reduction in tree selection. The impact of biotechnology on genetic studies has allowed the use of cutting-edge methodologies with forest tree species in spite of the late domestication process compared with crop species. The sequencing of the *Populus* genome has significant implications for forestry (Campbell *et al.*, 2003). *Eucalyptus* gene sequencing pursued by the Eucalypt Genome Initiative, The Eucalyptus Genome Sequencing Project Consortium and the Brazilian project Genolyptus. The Dendrome Project (http://dendrome.ucdavis.edu/cmap/) is a collection of forest tree genome databases and other forest genetic information resources, with a special emphasis on conifers (*Pinus*). It is in genome sequencing that research is currently most active.

Since genes regulating secondary tissue and lignin formation in the annual plant *Arabidopsis thaliana* were identified (Goujon and Jouanin, 2003), research on the genetic basis of wood quality in forest trees has significantly increased (mainly in *Eucalyptus, Pinus* and *Populus*). With the exception of micro-propagation, for which some applications are reported, most public domain information relates to research activities. Field applications appear extremely limited, according to the literature. Nevertheless, and in spite of unclear economic rationale, the use of biotechnology in forestry research has increased and provided new knowledge on tree biology and functioning. Commercial deployment of new biotechnology-based forest tree varieties of a limited number of taxa (*Eucalyptus, Pinus taeda, P. radiata, P. pinaster, Populus,* etc.) can be expected in the near future. The impact of biotechnology applications on global wood supply may, however, take longer to materialize at least not before 2020 (Seppala, 2003). In this

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context, genetic modification appears to be the most significant sector of forest biotechnology. DNA fingerprinting, through its high precision in identifying plant genotypes, holds considerable promise as a reliable tool of intellectual property protection of tree species. Genomics and proteomics outcomes are expected to boost conventional tree breeding and improve the efficiency of existing programmes.

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Indian Journal of Ecology

Wheat Yield Performance in Relation to Poplar Tree Density and Age (*Populus deltoides*) in Bet Area of Punjab

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Abstract: Wheat yield performance data was collected from farmers field at different tree densities (i.e. 225, 250 and 300 plants acre^{-1}) at different ages (1, 2, 3 and 4 years old) of poplar. The perusal of data revealed that there was non-significant difference in number of tillers and ear length under 225 and 250 trees per acre density, but these parameter reduced significantly at higher poplar density (300 plants acre^{-1}). Poplar density of 225 plants per acre produced significantly higher grain yield by 8.0 and 25.6 per cent as compared to 250 and 300 plants acre^{-1}, respectively. Ear length, test weight and grain yield were negatively correlated with increase in age of poplar. Test weight reduced significantly with age of poplar trees, which led significant decrease in wheat grain yield. Wheat yield under 2, 3 and 4 years old poplar reduced by the margin of 9.9, 26.9 and 49.8 per cent as compared to one year old poplar. Diameter at stump height and at breast height of poplar decreased with increase in poplar plantation density, but differences were not significant during initial two years.

Key Words: Agroforestry, poplar density, tree age, wheat

Poplar is a very prominent taxonomic group of tree species in plantation forestry as well as in natural forests in northwestern states in India. Its natural population is small and found only in the mountains with six indigenous species. As an exotic species (*Populus deltoides*), it acquire great role in afforestation/reforestation programmes, agro-forestry and conservation activities. According to India country report on poplars and willow (Anonymous 2012), area under poplar outside the forest in India is estimated 312,000 ha. The annual returns from poplar at current market rates are estimated to be around one Rs.60-80,000 rupees acre^{-1} year^{-1}, which is much higher than any other on-farm intervention (Dhiman, 2012a).

Poplar is an integral part of farming system and an important enterprise for farmers of bet areas of Punjab (Chauhan and Mangat, 2006). It has straight bole, small crown and winter deciduous nature that allows winter cropping with only marginal negative effect on crop yields. In the first 2 years of poplar, any crop can be grown as intercrop without much reduction (10–15%) in the yield during summer and winter seasons. Dhiman (2012b) identified that around 98% of the poplar block plantation have intercrops. However, during summer season, rice is not recommended for planting with poplar as flooding of rice often results in uprooting of trees (Dhanda *et al.,* 2008). Third year onwards, crops like wheat, oats, berseem, etc. can be grown successfully throughout its rotation. This is due to the ability of poplar to adapt to the wheat competition by distorting its root architecture that improves complementarity between trees and crops (Cannel *et al.,* 1996) as well as leaf fall starts in October and become totally leaf less in January and February. In a study by Sharma and Dadhwal (2011), wheat plant population was greatly affected during the leaf shedding stage of poplar. During dormant period of poplar, significantly lower values of plant height, leaf area index and dry matter yield of wheat were recorded. Gradual decrease in yield (10–46%) of intercropped wheat, with the increase in age of trees (first–sixth year) have been reported earlier by Gill *et al.* (2007). However, such yield loss is often compensated by the sale of poplar wood at the end of rotation (Chauhan *et al.,* 2009)). Competition for below and above ground resources often changes with the increase in tree age. The main objective of the study was to find out optimum poplar plant density for successful intercropping with winter crop i.e., wheat.

MATERIALS AND METHODS

Poplar is an important enterprise for farmers of bet areas of Punjab in district Ropar. Its falls between north latitude 30º -32´ and 31º-24´ and east longitude 76º-18´ and 76º-55´. Annual rainfall in the district Ropar was recorded 103.5cm during 2013-14. Farmers of bet area are growing poplar at different plant densities and intercrop with wheat during winter season. Data of poplar growth and wheat performance was collected from farmers field during the year 2013-14. The diameter at breast height (DBH) and diameter at stump height (DSH) of the trees were also measured. The various growth and yield attributes of wheat viz., number of tillers, ear length and 100-grain weight were recorded on harvesting of one square meter representative area from each field and grain yield, straw yield and harvest index were recorded from whole field.

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RESULTS AND DISCUSSION

Effect of poplar density: The perusal of data (Table 1) revealed that differences in number of tillers and ear length were non-significant under 225 and 250 trees per acre poplar plantation density, however, these parameter were significantly less under higher poplar plantation density (300 plants acre^{-1}) due to competition between poplar and wheat for space, light and nutrients in addition to this higher leaf litter fall under higher poplar density might be responsible for inhibits wheat germination/growth. Test weight decreased significantly with each increase in poplar population density led to significant decrease in wheat yield with each increase in poplar population density. Wheat crop under poplar density of 225 plants per acre produced significantly higher grain yield by the margin of 8.0 and 25.6 per cent as compared to 250 and 300 plants per acre, respectively. Grain yield recorded under 250 poplar plants per acre was significantly higher by 16.3 per cent than 300 poplar plant density. This reduction in test weight and grain yield might be due to lower production of photosynthates under low light conditions as the light intensity decreased under higher poplar plantation. Chauhan and Dhiman (2002); Chauhan *et al.* (2010) recorded influence of light reduction under poplar on wheat yield. Kaur *et al.* (2010) reported that all growth parameters showed inverse relationship with the age of plantation as number of tillers and 100-grain weight decreased under higher aged plantation. Similarly data presented in Fig. 1 showed that ear length, test weight and grain yield were negatively correlated with increase in age of poplar with R^2 values 0.189, 0.107 and 0.130, respectively. Straw yield and harvest index followed similar trend as number of tillers. Straw yield was significantly higher under 225 and 250 poplar plants per acre by the margin of 10.7 and 7.3 per cent, respectively as compared to 300 poplar plants per acre. Similarly harvest index was superior under 225 and 250 poplar plant per acre by 9.4 and 6.1 per cent, respectively than higher poplar plant density (300 plants acre^{-1}). Proportionally higher affect on grain yield than vegetative growth led to decrease in harvest index. Chauhan and Dhiman (2002) also recorded inverse relationship of wheat yield to row spacing.

Effect of age of poplar: An appraisal of the data presented in the Table 1 indicated that number of tillers and ear length of wheat were not affected up to two years growth of poplar plantation. The decrease in values thereafter with each year increase in age of poplar plantation was due to increased competitive interactions for light and soil resources. Chauhan *et al.* (2011) also reported that poplar at its earlier stage caused less harmful effect on crops but older trees reduced the plant stand due to more exploitation of resources by poplar trees. Kumar *et al.* (2001) reported significant impact of leaf fall on wheat seed germination, which could be reduced by removing the leaf litter. Sharma and Dadhwal (2011) confirmed that wheat plant population was greatly affected during the leaf shedding stage of poplar. Test weight recorded maximum under one year old poplar plantation and reduced significantly with the age of poplar plantation. Reduction in ear length and hundred grain weight with increase in the age of poplar was also reported by Gill *et al.* (2009). Reduction in these yield attributes led to significant decrease in wheat grain yield with each increase in the age of poplar. Grain yield under 2, 3 and 4 years old poplar reduced by the margin of 9.9, 26.9 and 49.8 per cent as compared to under one year old poplar. Chauhan *et al.* (2009) also recorded 11, 39, 50 and 54 per cent decrease in grain yield at one, two, three and four year old poplar plantation, respectively than the control. They also reported decrease in light intensity by 23, 35, 46 and 47 per cent (one to four year old poplar, respectively) than the open

Table 1. Wheat yield and yield attributes as affected by density and age of poplar

Treatment	Tiller m^{-1} row length	Ear length (cm)	100-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Poplar density acre^{-1}						
225	95.75	9.13	4.31	3.92	5.91	39.7
250	91.26	8.83	4.09	3.63	5.73	38.5
300	83.13	8.10	3.79	3.12	5.34	36.3
CD (0.05)	6.37	0.60	0.21	0.28	0.33	1.3
Age of poplar						
1 yr	100.86	9.76	4.71	4.54	6.85	39.8
2 yr	96.67	9.17	4.41	4.09	6.34	39.2
3 yr	88.17	8.41	4.03	3.32	5.42	37.9
4 yr	74.47	7.40	3.10	2.28	4.03	35.8
CD (0.05)	7.35	0.69	0.21	0.32	0.38	1.5

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Table 2. Diameter growth of poplar at different densities

Poplar density acre^{-1}	Diameter at stump height (cm)				Diameter at breast height (cm)			
	1 yr	2 yr	3 yr	4 yr	1 yr	2 yr	3 yr	4 yr
225	8.1	14.8	20.3	24.0	5.9	10.6	16.0	20.8
250	7.7	14.5	18.6	21.3	5.4	10.2	15.4	17.6
300	7.3	13.3	16.6	18.7	4.6	9.5	12.9	14.6

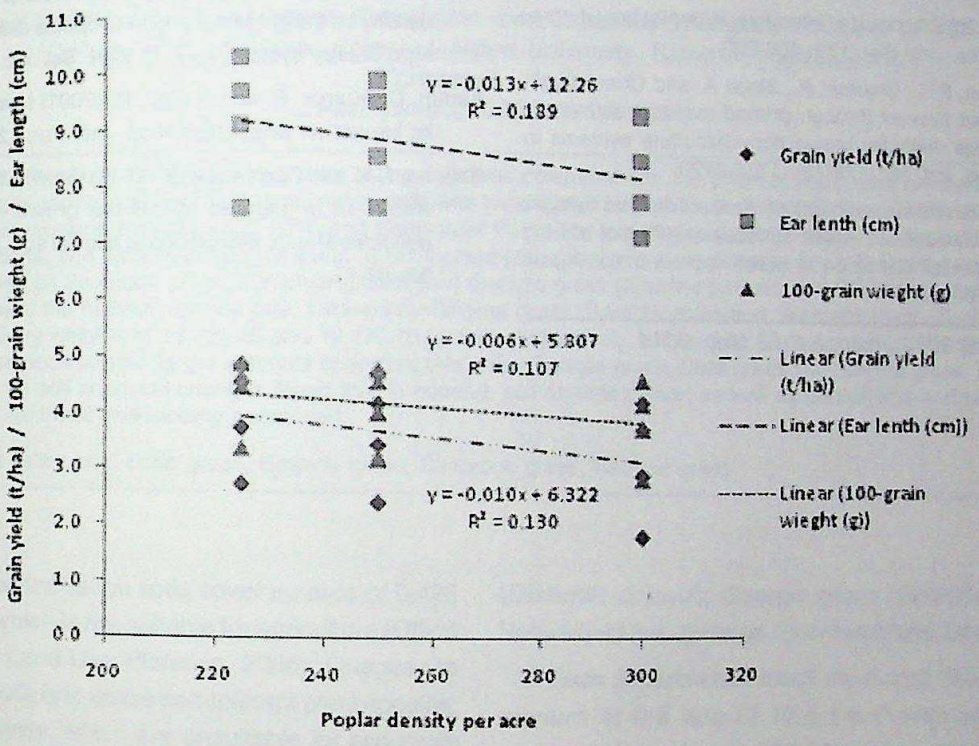

Fig. 1. Relationship between poplar plantation densities and; yield and yield attributes of wheat

condition, indicating that light becomes a limiting factor for reduction in crop yield. Similarly, trend followed in straw yield, decreased significantly with the age of poplar plantation. Significant reduction in yield may be due to lower production of photosynthates under low light conditions.

Poplar growth: Data presented in Table 2, revealed that poplar growth was not much affect by its densities up to two years, while during 3rd and 4th years poplar growth in terms of diameter at stump height (DSH) and diameter at breast height (DBH) was more in poplar density 225 plants acre^{-1} as compared to higher poplar plant densities and decreased with each increase in poplar plantation density. This indicates that the competition among threes induce during third year onwards, thus suitable measures are essentially required including fertilization, pruning, etc. Khan and Chaudhry (2007) also recorded positive relationship of tree growth with increasing tree spacng. Durai *et al.* (2009), however, recorded reduced diameter increment after fourth year at a low density of 400 trees ha^{-1}, therefore, with increase in density, the competition advanced to third year.

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Utilization of Salt Tolerant Species for Rehabilitation of Coastal Saline Soil in Petchaburi Province Thailand

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Abstract: The growth of various halophytes in coastal saline soils was compared and the effect of halophytes on changes in chemical properties of saline soils and rehabilitation of coastal saline soils was investigated at the Sirindhorn International Environmental Park, Cha-am district, Petchaburi province between April 2010 and September 2011. The experimental design was a randomized complete block design with 4 replications. The halophyte species were: i) Dixie grass (*Sporobolus virginicus* coarse type), ii) Smyrna grass (*Sporobolus virginicus* smooth type), iii) Seabrook grass (*Distichlis spicata*), iv) Georgia grass (*Spartina patens*), and 5) natural grasses. It was found that Dixie grass showed the highest survival rate, followed by Smyrna grass, Georgia grass and Seabrook grass. Seabrook grass had the highest fresh and dry weights of 19,796.25 and 12,178.75 kg ha^{-1}, respectively, followed by Georgia grass, Dixie grass and Smyrna grass. Seabrook grass accumulated larger amounts of sodium (Na) than Georgia grass, Dixie grass and Smyrna grass. The study of the effect of halophytes on soil chemical changes found that in general, soil organic matter, as well as phosphorus and potassium levels, increased, while soil electrical conductivity decreased.

Key Words: Coastal saline soil, Dixie grass, Smyrna grass, Seabrook grass, Georgia grass

In Thailand, coastal saline soils cover an area of 0.425 million ha, most of which is not suitable for agriculture (Office of Soil Survey and Land Use Planning, 2006). One way to rehabilitate saline soils is to utilize salt-tolerant plant species. In areas of high salinity, which are unsuitable for economic crops, many other plants can still be grown. Yuvaniyama and Arunin (1996a) found that Dixie grass (*Sporobolus virginicus* coarse type), Smyrna grass (*Sporobolus virginicus* smooth type), *Spartina patens*, *Distichlis spicata*, Kallar (*Leptochloa fusca*), and *Atriplex spp.* are well adapted to the highly saline soils of northeastern Thailand. On the other hand, Im-Erb *et al.* (1994) reported that *Spartina patens* had a higher survival rate than *Panicum repens*, Dixie grass, and Smyrna grass in coastal saline soils. The objectives of our research were to compare the growth of different halophytes in saline soils in coastal areas and to investigate the effect of halophytes on changes in the chemical properties of saline soils and their suitability for the rehabilitation of coastal saline soils.

MATERIALS AND METHODS

The research was carried out using a randomized completed block design with four replications. The tested halophytes that consisted of exotic halophytes were imported from the United States of America i.e., Dixie grass (*Sporobolus virginicus*, coarse type); Smyrna grass (*Sporobolus virginicus*, smooth type); Seabrook grass (*Distichlis spicata*); Georgia grass (*Spartina patens*) and Naturally-grown grasses (non-halophyte block).

Each experimental block measured 3x3 m. Farmyard manure at the rate of 12.5 t ha^{-1} was applied at soil preparation. On August 20th 2010, the 4 halophyte species were planted at plant spacing of 30x30 cm. Weed and pest controls were also employed. Soil samples were taken at a depth of 0-30 cm to determine the soil pH according to Peech (1965), soil electrical conductivity (EC_e) according to Rhoades (1982), soil organic matter according to Walkley and Black (1934), available P according to Bray and Kurtz (1945), available K and soluble Na according to Rhoades (1982).

Data on survival rates and biomass were collected thrice (December 2010, June 2011, and September 2011). The concentration of total N was determined according to AOAC (1990), total P according to Barton (1948), total K and total Na according to Jackson (1958). Data were suitably analyzed.

RESULTS AND DISCUSSION

Among the four halophyte species planted on August 20th, 2010, Dixie grass showed the highest survival rate, though it was only slightly higher than Smyrna grass and Georgia grass, while Seabrook grass had the lowest survival rate (Table 1). This result differed from that of Im-Erb *et al.*

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Table 1. Survival rate in 2010, fresh and dry weight of salt tolerant species on coastal saline soil

Salt tolerant species	Survival (%)			Weight (kg ha^{-1})	
	8 September	5 November	28 December	Fresh weight	Dry weight
Dixie grass	100.00	99.31	99.31	6,855.63	2,972.25
Smyrna grass	99.31	97.22	97.22	4,916.69	2,148.31
Seabrook grass	90.97	83.33	83.33	19,796.25	12,178.75
Georgia grass	94.44	94.44	93.05	8,827.81	3,929.06
LSD	9.53	8.80	9.06	6,586.00	4,323.20
C.V. (%)	6.43	6.10	6.31	42.33	52.87

(1994) who reported that Georgia grass had a higher survival rate than Dixie grass and Smyrna grass. Furthermore, Yuvaniyama and Arunin (1992) reported that Dixie grass and Smyrna grass can show survival rates of up to 100% at a salinity of 40 ppt NaCl. While Gallagher (1979) reported that *Sporobolus virginicus* is a highly salt-tolerant plant that can survive in media with salinity of 30%. These four species could survive because of their superb ability to excrete excess salt through their leaves.

Data on biomass were collected three times in December 2010, June 2011, and September 2011. Throughout the research period, Seabrook grass produced the highest fresh and dry weights of 19,796.25 and 12,178.75 kg ha^{-1}, respectively, which were significantly higher than for Georgia grass, Dixie grass and Smyrna grass (Table 1). However, the difference in fresh and dry weight also depends on the phenotype of the species.

The results suggested that the N, P, K, and Na concentrations varied with species, while the accumulation or uptake of N, P, K, and Na varied with the biomass of the specific species. N, P. K and Na accumulation of seabrook grass at both six and fourteen months were higher than in other grasses (Table 2).

Changes in Soil Chemical Properties

The average initial pH of the experimental plots was 7.15. However, all experimental plots showed an increases in pH by the end of the experiment, especially the Dixie grass plot, which had a pH value increase from 7.40 to 7.92 (Table 3). The EC_e values of all experimental plots were initially between 6.85 and 12.46 dS m^{-1}, which could be classified as moderately to severely saline. After the experiment was completed, all plots showed a decreases in EC_e, especially the plot with Seabrook grass whose EC_e decreased from 12.46 to 6.02 dS m^{-1}. The characteristics of specific species may affect the EC_e value. Seabrook grass has a creeper form that helps preserve soil moisture and reduce the accumulation of salt on the soil surface. These characteristics of Seabrook grass may affect its EC_e so that it decreased more than in the other species, which is consistent with the observations of Yuvaniyama and Arunin (1996b). In contrast, Sakai *et al.* (2012) reported that the levels of Na, Cl and EC_e in all test plots decreased after the growth of halophytes.

The organic matter of the soil and available P before the experiment was low; however, it had increased when measured at the end of the experiment, especially in the Seabrook grass plot where organic matter increased from 0.52 to 1.32% and P from 40.25 to 225.75Mg ha^{-1}. There was a general decrease in the amount of available K after the experiment, with an exception of the non-halophyte control plot with natural-grown grasses where the available K increased slightly. The soil in the Dixie grass, Smyrna grass, and Seabrook grass plots showed decrease in soluble sodium. This may have been a result of the species growth characteristics that helped to cover the soil surface and their

Table 2. Nutrient content (%) and nutrient uptake (kg ha^{-1}) of salt tolerant species at 6 and 14 months

Salt tolerant species	Age (month)	N		P		K		Na	
		Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake
Dixie grass	6	0.95	6.69	0.24	1.69	0.53	4.75	0.67	4.69
	14	0.97	13.44	0.16	2.19	0.68	9.44	0.65	9.00
Smyrna grass	6	1.12	5.06	0.39	1.75	0.80	2.75	0.80	3.63
	14	0.93	11.63	0.24	3.00	0.60	7.50	0.60	7.50
Seabrook grass	6	1.02	38.44	0.18	6.81	1.90	24.50	0.98	36.94
	14	0.97	57.81	0.18	10.75	0.65	38.75	0.62	36.94
Georgia grass	6	0.81	11.69	0.30	4.31	0.73	8.38	0.68	9.81
	14	1.00	7.63	0.15	1.13	0.58	4.44	0.68	5.19

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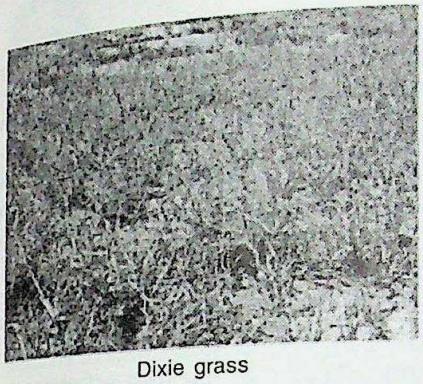
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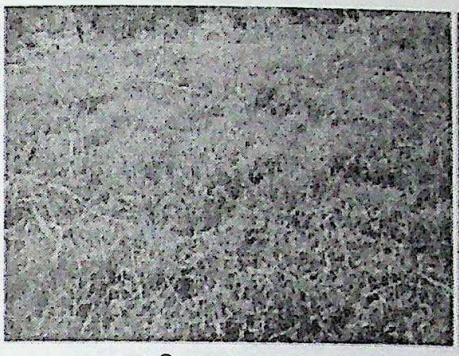
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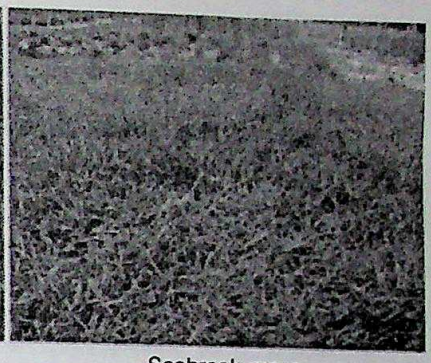
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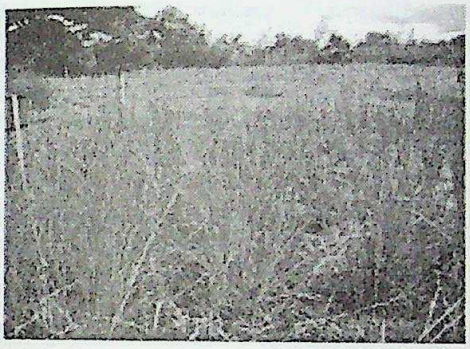
Georgia grass

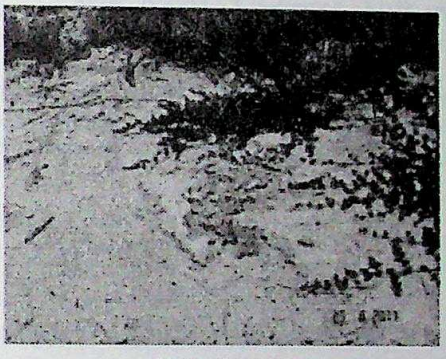
Natural grass

Table 3. Effect of salt tolerant species on change of soil properties

Salt tolerant species	pH		EC_e (dS m^{-1})		Organic matter (%)		Available P (mg kg^{-1})		Available K (mg kg^{-1})		Soluble Na^+ (m mol l^{-1})	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Dixie grass	7.15	7.92	6.85	2.75	0.46	0.85	11.25	33.65	240.00	188.25	60.05	28.74
Smyrna grass	7.30	7.85	8.95	3.31	0.48	0.98	16.75	86.55	215.00	200.00	81.00	38.24
Seabrook grass	7.13	7.52	12.46	6.02	0.52	1.32	40.25	225.75	228.75	170.00	109.82	63.45
Georgia grass	7.10	7.88	5.58	5.12	0.45	0.88	25.50	125.00	198.75	177.50	49.57	61.62
Natural Grass	7.08	7.78	7.35	5.70	0.60	0.95	28.25	135.25	208.75	212.5	64.85	68.17

mechanism to absorb salt from the soil and excrete excess salt through the stomatal leaves, thus reducing soluble sodium in the soil. This observation is consistent with Yuvaniyama and Arunin (1996b). On the other hand, the amount of soluble sodium in the Georgia grass and the non-halophyte blocks increased.

CONCLUSIONS

Dixie grass showed the highest survival rate while Seabrook grass had the highest growth, fresh and dry weights, and the best nutrient accumulation especially of nitrogen and sodium. Growing Seabrook grass resulted in a greater reduction in electrical conductivity and sodium in the soil than from planting the other grasses or allowing grasses to grow naturally. Seabrook grass also seemed to improve the soil fertility more than the other grasses.

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Litterfall, Carbon and Nutrient Returns in Stands of *Ceiba pentandra* (L.) Gaertn. Subhumid Tropics of Eastern India

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Abstract: The study was conducted in a nine-year old *Ceiba pentandra* (L) Gaertn. stands planted in a three tree spacing 4 x 4 m, 4 x 6 m and 4 x 8 m and two pruning regimes. Litterfall samples were collected from the field of *C. pentandra* for 12 months. The litterfall occurred throughout the year showing significant differences between tree spacing, pruning regimes and months. Total litterfall includes tree components (leaf litter + wood litter + flower litter + pod litter) ranged from 0.451 to 1.153 Mg ha^{-1} throughout the year. Total litterfall followed unimodal pattern with highest peak in April and lowest in August. In different tree spacings, total monthly litterfall, leaf litter contributed from 59 to 60 %, wood litter from 30 to 31.6 %, flower litter from 2.4 to 3.0 % and pod litter from 6.2 to 6.8 %. Litterfall was significantly higher in 4 x 4 m and lower in 4 x 8 m tree spacing. The study showed that litterfall was strongly and positively correlated with temperature and negatively correlated with relative humidity. The *C. pentandra* stands with high density returned highest amount of C and nutrients to soil.

Key Words: Litterfall, pruning, carbon, nutrient returns, *Ceiba pentantra*

India is one among the important tropical countries, which have renewed its interest as part of global and national policies to rehabilitate 175 m ha of the degraded lands. Over exploitation, shifting cultivation, uncontrolled wind and water erosion, soil salinity, alkalinity and poor land management in the last few decades virtually transformed 100 m ha into wasteland (Ravindranath and Hall, 1994). This large tract of degraded land mass of India has vast potential and could become crucial in national and global efforts to enhance carbon sequestration. National agriculture policy (2000) also envisaged restoring degraded lands by tree farming or through agroforestry practices. Both agroforestry and tree plantations have strong potential for sequestering carbon as they could sequester 0.8 to 2.2 pg of carbon per year globally over a period of 50 years time frame (Dixon *et al.*, 1994). Carbon management has tremendous potential to increase productivity of degraded lands since it improves fertility/nutrient use efficiency and also contribute positively to soil quality by improving porosity, available water holding capacity and cation exchange capacity (CEC), improve pH, help in increasing yields and economical returns per unit of land (Delgado and Follett, 2002). Land management practices *viz.* agroforestry and monoculture tree plantations have different impacts on development of soil organic matter and nutrient pools. Plants get their nutrients from the soil in which they grow. As the plants develop, they shed their leaves and branches as litter which decays to enhance the nutrients of the soil that are again used up by plants a process known as nutrient cycling (Wood *et al.*, 2006). The most important concern of litterfall studies is the quantification of this process as a principal way in nutrient cycling, and the analysis of the efficiency of this cycle (Proctor, 1983). The data on litterfall is useful for predicting the productivity of an ecosystem. Litter production depends on tree species, environmental conditions and management practices followed in plantations. Different species have distinct growth and phenological stages and thus show variation in their litterfall pattern, which is correlated to weather conditions. The amount of litterfall could be modified through pruning management quantity as well as quality of litter could be affected by land management practices. There have been efforts to find the relationship between climatic variables and litter production at regional levels. Williams and Tolome (1996) reported that some tropical tree species showed a positive correlation of litterfall with maximum temperature. Williams *et al.* (1997) observed that leaf fall coincide with the attainment of the seasonal minimal level in leaf water potential. There is a need for a narrower, location-specific investigation of the interaction of climatic variables and litter production if the processes involved are to be well understood.

Choice of tree species plays a key role and influences both trajectories of growth rate, biomass production, carbon sequestration and nutrient cycling in agroforestry systems. *Ceiba pentandra* (L), commonly known as silk cotton tree is a fast growing multipurpose tree and proved as one among the promising species for agroforestry practices (Rajendran *et al.*, 2002). Because of the straight bole, acute branching and deciduous nature and potential to produce high quality

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floss and seeds at early age made the species as an ideal choice of farmers to practice in agroforestry. Gawali (2003) evaluated that the total biomass production in nine year old *Ceiba pentandra* stands contributed highest in stem 45.3 to 47.7 % fallowed by root 22.8 to 22.9 %, branch 16.75 to 17.84 %, pod 6.36 to 9.11 % and leaf 5.82 to 5.92 % tree component.

This study aimed to quantify the litterfall production in nine-year old *Ceiba pentandra* stands; find out correlation between climatic variable, litterfall and quantify the carbon and NPK nutrient elements returns to soil.

MATERIALS AND METHODS

The study site, agriculture field of Department of forestry, IGAU, Raipur, Chattisgarh state is situated in eastern India. It lies at 21.76 ^{0}N latitude and 81.36 ^{0}E longitude having an altitude of 295 m above mean sea level. The climate is sub-humid tropical with an average rainfall of 1250 mm. Most of the rainfall (90%) is received during monsoon season from second week of June to third week of September. Average number of rainy days from 60 to 79. Mean monthly maximum temperature in study site ranges from 30.9 ^{0}C in December to 43.3 ^{0}C in May, while the minimum temperature varies from 11.9 ^{0}C in December to 28.3 ^{0}C in May. Maximum temperature occasionally goes beyond 45 ^{0}C for few days in May and minimum even falls below 10 ^{0}C in December. Relative humidity is generally highest in July and August, while it is lowest during April and May. The mean relative humidity varies from 82 % in Augest to 32 % in May. The measurement of different climatic variables were carried out in the open at the central weather station of Agrometeorology Department, I.G.A.U. Raipur, India.

Experimental design and sample collection: The litterfall study was conducted in a split-split-plot design with four replicates (Gomez and Gomez, 1984). Litter was collected at monthly intervals from September to August by randomly placing litter traps 0.5 x 0.5 m beneath tree in different treatments. Twenty-four (3 tree spacing x 2 pruning x 4 replicates) traps were placed for collection of litter production. The litter collected from the traps in various treatments were sorted and separated into different components *viz.*, leaf, wood, flower and pods. These samples placed in a paper bag, and dried in an electric oven at 70 ^{0}C temperature until they reach constant weight. The different components of litter were summed to obtain total litterfall. The litterfall recorded in traps was extrapolated to hectare basis and later converted in to Mg ha^{-1}. The oven dry litter collected for twelve months was summed to derive annual litter production.

Laboratory analyses of samples: The different components (12 months) of litter were bulked and composite sample was prepared. Four sub samples of litter were randomly drawn from composite sample and oven dried at 70^0 C temperatures for 72 hrs. The oven dried samples were ground in a Wiley mill and pass through 2 mm sieve before chemical analysis. The litter was analysed for total carbon on solid sample module using automatic carbon analyzer (SSM-5000A). Total nitrogen was analysed in concentrated H_2SO_4 -using a catalyst mixture (Potassium sulphate and Copper Sulphate in ratio 9:1) with KEL PLUS digestion unit. The total nitrogen was estimated following micro-kjeldhal method. Phosphorus and Potassium were estimated after digesting sample in diacid mixture (HNO_3 and $HClO_4$ in 9:4 ratio). Phosphorus was determined by Vanado-molybdo phosphoric yellow colour procedure and potassium by Flame Photometer method (Jackson, 1967). Carbon and nutrient status Kg ha^{-1} were obtained from the product of litter biomass and average C and nutrient concentration.

Data collected was analyzed in laboratory and the result was subjected to descriptive and inferential statistical analyses using the MSTATC 1.41 Version.

RESULTS AND DISCUSSION

Litterfall pattern in *Cieba*: Tree spacing, pruning and monthly litter collection had significantly influenced leaf litter production In different tree spacings, monthly leaf litter production ranged from 0.436 to 0.449 Mg ha^{-1}. Leaf litter was significantly higher in 4 x 4 m and lower in 4 x 8 m tree spacing. Significantly higher leaf litter was produced in unpruned compared to pruned trees (Table 1). Wide variation was observed in leaf litter production in different months. Peak leaf litter was observed in January and lowest in August. Litterfall showed distinct monthly variations. Through out the year leaf litter ranged from 0.267 Mg ha^{-1} to 0.614 Mg ha^{-1}. The cumulative leaf fall indicated unimodal pattern with a peak in April (Fig. 1). Jamaludheen and Kumar (1999) also observed unimodal distribution of litterfall in *Acacia*, *Ailanthus*, *Pterocarpus* and *Casuarina* plantations. Higher litter fall values were observed in dry compared to wet season. The peak of litterfall in the tropics coincides with the dry season (Jhon, 1973).

Wood litter varied significantly due to differences in tree spacing, pruning regimes and months. A maximum wood litter amounting 0.241 Mg ha^{-1} month^{-1} was produced in 4 x 4 m followed by 0.221 Mg ha^{-1} month^{-1} in 4 x 6 m and 0.217 Mg ha^{-1} month^{-1} in 4 x 8 m tree spacing. The maximum wood litter of 0.227 Mg ha^{-1} month^{-1} was produced under unpruned compared to pruned treatment 0.225 Mg ha^{-1}. The maximum wood litter was produced in March and lowest in September.

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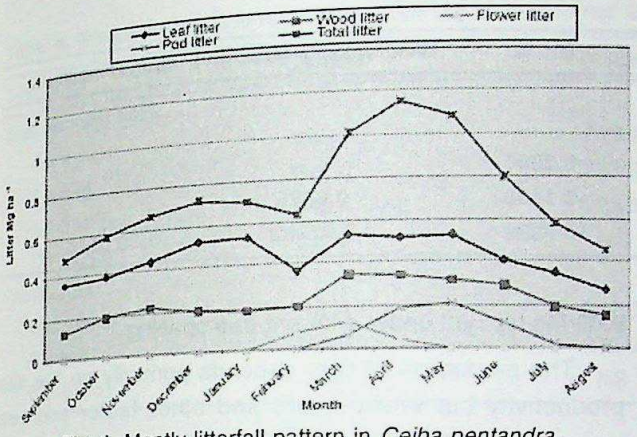

Fig. 1. Montly litterfall pattern in *Ceiba pentandra*

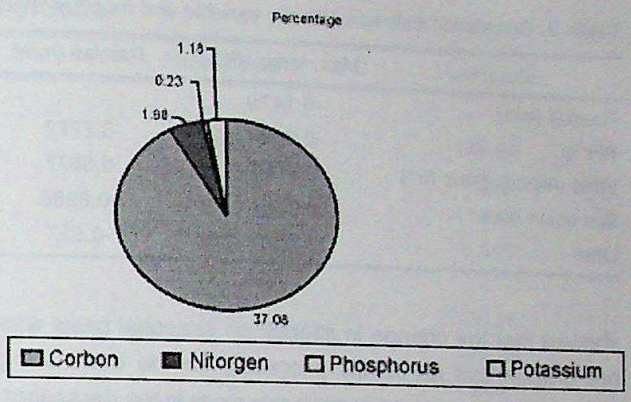

Fig. 2. Carbon and nutrient returned to soil through litterfall

Wood litter ranged from 0.124 to 0.335 Mg ha^{-1}. Interactions between tree spacing x pruning, pruning x month, spacing x month and spacing x pruning x month were statistically significant for wood litter (Table 1). This may be related to the phenology of the *Ceiba* tree associated with the edaphic factors, where due to high water stress conditions in summer (high temperature and low humidity), trees will rapidly defoliate. Leaf fall of the most dominant speices was asynchronous. Besides, the higher pod and twig litter added to other litter components, thus cumulatively more litterfall was observed during this period. The rapid loss of foliage is mechanism of combating drought during summer by the species. This phenomenon was also observed by Nwoboshi (1981) where rapid shedding of litter by teak in south western Nigeria in dry season was occurred to withstand drought. Litterfall is not only affected by water scarcity, more likely it is the result of the interaction of different factors i.e, resource availability, heavy winds, soil characteristics, mineral deficiency and the rain mechanical effects (Jhon, 1973).

Litter from floral component also significantly affected by both tree spacing and pruning treatments. Monthly variation was also significant for this component. It ranged from 0.023 Mg ha^{-1} to 0.018 Mg ha^{-1} in different tree spacing. It was significantly higher in 4 x 4 m tree spacing, which gradually reduced with an increase in tree spacing. The maximum litter from floral components was found in unpruned than pruned stands. It was highest in March (0.122 Mg ha^{-1}). Pod litter ranged from 0.052 to 0.045 Mg ha^{-1} in different tree spacings, which was highest in 4 x 4 m and lowest in 4 x 8 m tree spacing. The unpruned stands produced significantly higher pod litter compared to pruned trees. Pod litter was produced from March to July. The highest amount of pod litter was produced in May. Total litterfall (leaf litter + wood litter + flower litter + pod litter) significantly ranged between 0.721 to 0.761 Mg ha^{-1} month^{-1}. It was highest in 4 x 4 m, while lowest in 4 x 8 m 0.721 Mg ha^{-1} tree spacing. The total litter was statistically at par in 4x6 m and 4 x 8 m tree spacings. Significantly highest litter of 0.766 Mg ha^{-1} was produced in unpruned than pruned condition. Total litterfall followed unimodal pattern with highest peak in April and lowest in August. In different tree spacings, for total monthly litterfall, leaf litter contributed from 59 to 60 %, wood litter from 30 to 31.6 %, flower litter from 2.4 to 3.0 % and pod litter from 6.2 to 6.8 % (Table 1).

Correlation between climatic variable and monthly litterfall: The litterfall is strongly correlated to the climatic variables. It was established that the maximum temperature and minimum humidity influenced litterfall. This study

Table 1. Monthly litterfall pattern in different components of *Ceiba pentandra* (Mg ha^{-1})

Treatment	Leaf litter	Wood litter	Flower litter	Pod litter	Total litter
Tree spacing (S)					
4 x 4 m	0.449	0.241	0.023	0.052	0.761
4 x 6 m	0.438	0.221	0.017	0.048	0.725
4 x 8 m	0.436	0.217	0.018	0.045	0.721
CD (0.05)	0.414	0.013	0.007	0.011	0.242
Pruning (P)					
Unpruned	0.456	0.227	0.021	0.056	0.766
Pruned	0.425	0.225	0.017	0.041	0.705
CD (0.05)	0.0147	0.013	0.006	0.011	0.036
S x P	0.0202	0.0182	NS	0.015	0.0504

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Table 2. Correlation between climatic variable and monthly litterfall

	Max. temp. (ºC)	Rainfall (mm)	RH %	Wind velocity (kms hr^{-1})	Sun shine hour
Rainfall (mm)	-0.1479				
RH %	-0.9384	0.2772			
Wind velocity (kms hr^{-1})	0.5186	0.6677	-0.3996		
Sun shine hour	0.0567	-0.8285	-0.1538	0.6636	
Litter	0.7520	-0.527	-0.8332	0.02982	0.5144

showed that the change in litterfall on seasonal basis was not gradual but an erratic process with the dominating climatic variables asserting their role more in the dry season than in the rainy season. It was not the shift from one season to the other that made the difference in quantity of litter produced, but the interactions of relevant climatic variables within seasons, which also had differing effects depending on the phenological characteristics of species. Lugo *et al.* (1978) reported positive correlation between litterfall and temperature and rainfall. Agbim (1987) found a significant negative correlation between *Chromolaena odorata* litterfall and atmospheric relative humidity in a study conducted in the dry season in Southern-Eastern Nigeria. Regression analysis showed that only 58.88 % variation in litterfall was explained by temperature, whereas, relative humidity explained 74.48 % variation in total litterfall. Earlier studies also showed that only a fraction of total litterfall will be well explained during particular season. Vogt *et al.* (1986) reported that climatic variables (latitude, temperature and precipitation) could explain 50 % of the variation in above ground litterfall for broadleaved forest of the world, but they were poorly related to data analyzed for needle leaved forests. Vitousek (1984) also reported that the interaction of temperature and precipitation was significant for litter production in the tropics.

Annual litter production: Perusal of data on results indicated that tree spacing had significantly influenced component wise and total annual litterfall (Table 3). In different tree spacings, total annual litter varied from 8.65 to 9.09 Mg ha^{-1} yr^{-1} under different tree spacing.

The production of litter depends primarily on the site productivity but environment and other factor such as temperature, water and nutrient availalblity limit production. Litterfall data for the *Ceiba* species in similar age groups in their natural forest environment and plantation are not available for comparison with present study. Litterfall production is within the range and comparable with litterfall reported by Rajgopal *et al.* (2001). Jamaludheen and Kumar (1999) reported that annual litter production in 8-9 year old stands was highest (12.69 Mg ha^{-1} yr^{-1}) in *Acacia* followed by *Paraserinthes* (9.17 Mg ha^{-1} yr^{-1}) and lowest in *Peterocarpus* (3.42 Mg ha^{-1} yr^{-1}). The present study also showed significant effect of tree density and pruning on annual litter production. It was higher under 4 x 4 m tree spacing and gradually decreased with increase in tree spacing.

The greater number of trees and prolonged shade conditions contributed for higher litter production in 4 x 4 m spacing. Pruning of trees had reduced total litter production by 7.8 %. It is proven fact that pruned trees contain lower foliage biomass and thus they contribute lower litterfall. George and Kumar (1998) and Jamaludheen and Kumar (1999) showed lower annual litter production under pruned stands of *Acacia auriculiformis*, *Paraserianthes falcataria*, *Pterocarpus marsupium* and *Artocarpus herterophyllus* in silivipastoral and wood lots system. Age, stand density and/or stage of stand development are also major determinants of litterfall. Litterfall increases with stand age and/or unite

Table 3. Annual litter production (Mg ha^{-1})

Treatment	Leaf litter	Wood litter	Flower litter	Pod litter	Total litter
Tree spacing (S)					
4 x 4 m	5.42	2.98	0.76	0.62	9.09
4 x 6 m	5.25	2.65	0.18	0.57	8.69
4 x 8 m	5.23	2.59	0.25	0.54	8.65
CD at 5%	NS	NS	0.04	0.003	NS
Pruning (P)					
Unpruned	5.47	2.72	0.20	0.66	9.18
Pruned	5.10	2.61	0.19	0.46	8.46
CD at 5%	NS	NS	NS	NS	NS

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Table 4. Annual carbon and nutrient addition (kg $ha^{-1}yr^{-1}$) to soil through litterfall

Treatment	Carbon	Nitrogen	Phosphorus	Potassium
Tree spacing (S)				
4 x 4 m	385.1	239.1	23.7	142.81
4 x 6 m	372.0	233.9	22.3	128.8
4 x 8 m	345.4	228.5	21.7	119.45
CD (0.05)	0.032	NS	NS	0.145
Pruning (P)				
Unpruned	367.4	242.0	23.7	134.25
Pruned	359.0	282.0	20.8	127.29
CD (0.05)	0.04	NS	NS	0.04

Table 5: Comparative account of nutrient via litterfall in plantation and agroforestry system in India

System	Tree species	Age (yr)	Nutrient (kg ha^{-1} yr^{-1})			Source
			N	P	K	
Woodlots	*Acacia auriculiformis*	9	203.0	15.7	12.6	Jamaludheen and Kumar (1997)
Plantation	*Populus deltoides*	4	91-148	8-15	70-99	Lodhiyal and Lodhiyal (1997)
Plantation	*Dalbergia sissoo*	7	74.8-108.4	5.6-8.4	8.7-46.9	Lodhiyal *et al.* (2002)
Plantation	*Ceiba pentandra*	9	228.5-239.1	21.7	119.4-142.8	Present study

canopy closer (George and Kumar, 1998). Similar trend in litter contribution by different component in other species was observed by Rajgopal *et al.* (2001), Jamaludheen and Kumar (1999).

Concentration of Carbon and Nutrients in Littermass

The study showed that nutrient concentrations varied as 1.98% N, 0.23% P, 1.18% K and 37.08% C. Concentration of nutrients in litter in *Ceiba* was comparable to litter nutrient concentrations in other species (Rajagopal *et al.*, 2001; Jamaludheen and Kumar, 1999; Salako and Tian, 2002).

Carbon addition in soil through annual litter fall in *C. pentandra* stands ranged from 345.4 to 385.16 kg ha^{-1} yr^{-1}. Annual C addition to soil through litter was highest in 4 x 4 m and lowest in 4 x 8 m tree spacing (Table 4). The higher C return to soil in 4 x 4 m was due to comparatively higher amount of litterfall in these stands. Similarly, the unpruned stands had produced greater amount of litter compared to pruned trees resulted in higher C content in former and lower C in later stands. George and Kumar (1998) also emphasised the higher age and high density, where the canopy closure became full will produce highest amount litterfall, which return highest amount of C and nutrients to soil. Quantity of nutrients returned to soil via annual litterfall ranged from 228.55 to 239.10 kg N ha^{-1} yr^{-1}, 21.79 to 23.74 kg P ha^{-1} yr^{-1} and 119.45 to 142.81 kg K ha^{-1} yr^{-1} (Table 4). Significantly higher amount of all these nutrients returned in soils under 4 x 4 m tree spacing compared to other tree spacings. A similar trend in nutrient return from poplar plantations was observed by Lodhiyal *et al.* (1995) and multipurpose trees by George and Kumar (1998).

The comparative accounts of nutrient via litterfall in plantations and agroforestry system of multipurpose tree in India are depicted in Table 5. As compared to the tree species, *Ceiba* showed the higher N ,P and K nutrient release to soil through litter fall.

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Estimation of Genetic Parameters for Growth and Wood Characteristics in Commercially Important Clones of Willow

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Abstract: Introduction work on willows in India is directed towards the development and screening of wide range of species and clones of diverse genetic origin. Twenty-five clones from five countries were evaluated for various growth and wood characteristics. Maximum values for plant height (290.35cm) and collar diameter (17.38mm) were recorded for clone 799 (U.K.). The highest value for shoot fresh weight (243.25gm), shoot dry weight (138.94gm), root fresh weight (184.05gm) and root dry weight (102.87gm) were recorded for Kashmir willow (U.K.). Clone SE-75-001 (Italy) and Kashmir willow (India) showed the highest values in wood density (0.58) and fibre length (0.81), respectively. Heritability (broad-sense) was recorded maximum (99.78%) for leaf area followed by wood density (56.10%), and fibre length (55.29) depicting stronger genetic control of these characteristics. Maximum genetic gain (61.58%) was recorded for leaf area that was closely followed by number of branches (60.39%). Growth characteristics were found to have positive and significant correlation with most of the characters, only wood density was recorded to have negative correlation with other traits. Total dry weight was recorded maximum loading value and can be recommended for selection on the basis of principle component analysis.

Key Words: Willows, heritability, genetic gain, correlation, wood density, fibre length, PCA

The willows (genus *Salix)* consists of about 350-500 species world wide occurring mostly in the arctic region and north temperate zone but some in the southern hemisphere covering tropical and subtropical area (Argus, 1997). In India few introduced species have been sporadically cultivated in the foot hills and inner valleys of Jammu & Kashmir, Himachal Pradesh, Uttarakhand and the northeastern regions of India for many years. Among them, the most popular clone is cricket bat willow, *S. alba* var. *coerulea* (Desch and Dinwoodie, 1996) which is a female cultivar of hybrid origin between *S. alba* and *S. fragilis* (Stott, 1984) and was introduced by the Britishers in Jammu and Kashmir state in the beginning of the 20th century.

The inherent benefits associated with willow have been recognized and recorded for millennia, with references to willow for medicinal uses and basket production by both the Egyptians and Romans. The ability of many species of willow to coppice vigorously and develop from unrooted cuttings was recognized and used by native Americans as part of their management and use of the species for medicinal purposes and as construction material for a wide array of items including sweat lodges, furniture, baskets, rope, whistles, arrows and nets (Masoodi *et al.,* 2008). In some regions, willow cuttings were actively used to stabilize stream banks that were prone to erosion (Gregory and Timothy, 2006). They are a source of cheapwood, indispensable for stabilization of soil on slopes river banks, nutrient filters, biomass energy plantations and phytoremediations (Christersson, 1986). In terms of productivity, 44m^3 ha^{-1} $year^{-1}$ has been reported in 4 x 4 m spacing at 6 year rotation in Argentina. Similarly 10 m height at 2 years age was also obtained in outstanding willow hybrids (Arreghini and Cerrillo, 1996). 19m plant height and 106cm girth has been observed in *Salix alba* under agroforestry system in six year rotation and this can be compared with any clone of Poplar in India. Both tree and shrub willow can be grown on short-rotation coppicing system where animals can browse to supplement pasture feed supply. Several willows have aesthetic features associated with growth habit, foliage, catkins or shoot colour that makes them particularly suitable for ornamental purpose on farms, parks or large gardens.

Salix tree improvement projects are in progress around the world because willows are used in many different ways. Research mission include the study of willow taxonomy, morphology, physiology, cultivation practices, advanced breeding molecular fingerprinting and genome mapping (Kuzovkina *et al.*, 2008). Efforts to improve biomass willows by breeding are currently hampered by the limited information available on genetic diversity, differences in flowering phenologies and on genetic relationships within and among species, clones, and hybrids in the gene pool. Differing flowering phenologies have been observed among willow species, which may have been evolved to restrict natural hybridization, and must be considered for controlled breeding (Choudhary *et al.*, 2011).

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Tree willows have direct bearing in order to diversify short rotation forestry under different agroforestry systems in India. The genetic base for willow improvement has been significantly broadened by assembling large collection of exotic species and their hybrids. The genetic variation at field level through multilocation testing is underway. Very significant clonal differences were observed in many qualities of wood, bark and foliage.

MATERIAL AND METHODS

The experiment was conducted in the Department of Tree Improvement and Genetic Resources, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The present study included total 25 clones of genus *Salix* from five different countries namely UK, Italy, New Zealand, Croatia and Turkey (Table 1). The 25 clones were selected based on their performance from initial screening experiment done on the basis of plant height and collar diameter at Departmental Naganji Nursery, Solan (HP). Twelve cuttings of each clone of standard size in complete randomized block design were planted at 40 cm X 30 cm. spacing in four replications. The uniform irrigation, weeding and other cultural practices were applied and observations on growth (plant height, collar diameter, number of branches, leaf area), biomass and wood characteristics (specific gravity and fibre length) were recorded in the month of December.

The data obtained for natural variation were subjected to statistical analysis using RBD design. The statistical analysis for each parameter was carried out on mean values and the analysis of variance (ANOVA) and covariance was worked out using standard procedure given by Panse and Sukhatme (1967) and Singh and Chaudhary (1985). Coefficient of variability was calculated as given by Burton and De-Vane (1953). The expected genetic advance at 5 per cent selection intensity was calculated by the formula suggested by Lush (1937), and genetic gain was worked out following the method suggested by Johnson *et al.* (1955).

RESULT AND DISCUSSION

The growth, biomass and wood characters viz., plant height, collar diameter, number of branches, leaf area, shoot fresh weight, root fresh weight, shoot dry weight, root dry weight, total green biomass, total dry biomass, wood density and fibre length depicted highly significant differences among all the clones (Table 2). Analysis of variance revealed highly significant differences among different genotypes of *Salix*, thereby indicating existence of variability for different characters undertaken for study. The results are in conformity with findings of Huse *et al.* (2008) on willow where significant variance in clones with respect to different growth characteristics were reported.

In consonance with the present study, Vihera-Aarnio (1988) had also noticed large variation for willow clones with respect to shoot length, collar diameter, above ground biomass (shoot biomass) and length of growing season. Similar findings were obtained on *Salix* and *Populus deltoides* (Tharakan *et al.*, 2005) and on Salix (Tunctaner, 2002). Wood samples of various clones showed a wide variation in wood density (0.39-0.58gcm^{-3}). Significant differences existed among the clones for fibre length, ranged between 0.59-0.81mm. Clone SE-75-001(Italy) and Kashmir Willow (U.K.) exhibited maximum wood density (0.58 gm cm^{-3}) and fibre length (0.81 mm). The results are in conformity with the findings on *Salix* species (Deka *et al.*, 1992; 1994 and Pan *et al.*, 1998).

Estimate of genetic parameters: The observed variation in a character is partly composed of genetic (heritable) variation and partly of non-heritable. Heritability and genetic advance provide the information of total variation present in the population and simultaneously gives an indication of the influence of environment on the character under study. Broad sense heritability is a measure of the gain, one can expect from clonal selection.

The growth, biomass and wood characters showed wide range of values (Table 3), indicating the extent of variation existing in the clones. Coefficient of variation was found maximum in shoot fresh weight (36.59%) and minimum in leaf area (1.37%). GCV was recorded maximum (39.85) for number of branches, while minimum (6.54) was exhibited by fibre length. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the characters. High heritability (99.78) was recorded for leaf area, whereas number of branches, wood density and fibre length registered moderate heritability with wide range (10.02-61.58) of genetic gain. This shows scope for further improvement through clonal selection. Similar findings were observed during study on clonal variation, heritabilities, genetic gain, genotypic and phenotypic correlations and efficiency of indirect selections in clonal test of *Salix* clones (Vihera-Aarnio, 1988; Zsuffa *et al.*, 1993) and *Populus deltoides* (Rawat *et al.*, 2001).

Since the leaf area, wood density, root fresh weight, total green biomass, root dry weight and total dry biomass showed higher heritability percentage, the selection for these traits would be quite effective and expected improvement would be achieved through mass selection. High heritability indicates the effectiveness of selection based on good phenotypic performance but does not necessarily mean a high genetic gain for a particular trait. Heritability

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Table 1. Description of the willow clones selected for study

S. No.	Clones	Scientific name	Source country (procured from)
1.	PN-733	*Salix nigra*	New Zealand
2.	17-93-A	*S.alba*	New Zealand
3.	SE-63-016	*S.jessoensis*	Italy
4.	PN-722	*S.matsudana*	New Zealand
5.	212/03	*S.matsudana X S. caprea*	U.K.
6.	84/11	*S.alba*	Turkey
7.	MB-368	*S.alba*	Croatia
8.	PN-227	*S.matsudana*	New Zealand
9.	SI-64-017	*S.alba*	Italy
10.	NZ-1002	*S.matsudana X S.alba*	New Zealand
11.	795	*S.matsudana X S.alba*	U.K.
12.	SI-63-007	*S.alba*	Italy
13.	V-99	*Salix X rubens*	Croatia
14.	NZ-1179	*S.matsudana X S.alba*	U.K.
15.	PN-721	*S.matsudana X S.alba*	New Zealand.
16.	131/25	*S. alba X S. babylonica*	U.K.
17.	799	*S.matsudana X S.alba*	U.K.
18.	PN-731	*S.nigra*	New Zealand
19.	NZ-1040	*S.matsudana X S.alba*	New Zealand
20.	NZ-1140	*S.matsudana X S.alba*	U.K.
21.	SE-75-001	*S.matsudana*	Italy
22.	NZ-1130	*S.matsudanaa X S.alba*	New Zealand
23.	V-311	*S.matsudana*	Italy
24.	SE-69-002	*S.matsudana*	Italy
25.	Kashmir willow	*S.alba cv coerulea*	U.K.

estimates in broad sense will be reliable if accompanied by high genetic gain. Heritability estimates along with expected gain is more useful and realistic than the heritability alone predicting the resultant effect for selecting the best genotype in poplars and willows (Singh *et al.*, 2001; Lin and Zsuffa, 1993).

High estimates of genetic advance expressed in percentage of mean (genetic gain) was observed for root fresh weight, root dry weight, total green biomass, total dry biomass, number of branches and leaf area for all the genotypes. In present investigations, high estimates of heritability along with high genetic gain was observed in root fresh weight, root dry weight, total green biomass, total dry biomass and leaf area. This indicates the higher proportion of additive gene effects for expression of these traits. Hence individual clone selection for these traits would be attempted for the effective improvement of these characters.

Jha (2002) recommended that at age one year, selections should be based on height and at the age two selection is to be practiced based on volume index, however, the dry weight biomass which is the key character for the selection of productive genotypes in fast growing tree species for screening of genotypes in nursery was not studied. On the other hand, both wood density and fibre length exhibited moderate heritability coupled with low genetic gain which indicated that these characters are more under control of non-additive genes. Hence, to make effective improvement in these characters, one has to go for heterosis breeding followed by clonal propagation in order to capture additive and non-additive genetic variances (Li *et al.*, 1993; Li and Wu, 1996)

Moderate heritability values for wood density (56.10) and fibre length (55.29) were obtained in the present study. The findings revealed strong genetic control for wood density and fibre length among *Salix* clones.

Principal component analysis: Principal component analysis is a multivariate statistical technique, which helps to reduce the data with large number of correlated variable into a substantially smaller set of new variables, through linear combination of variables that account most of the variation present in the original variables. Here in principal component analysis some information contained in original variables has to be sacrificed, but has an advantage that

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Table 2. Mean values of growth, biomass and wood characteristics of 25 clones of willow

Clones	Height (cm)	Collar diameter (mm)	Number of branches	Leaf area (cm^2)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight(g)	Total greenbiomass (g)	Total dry biomass (g)	Wood density ($g\ cc^{-1}$)	Fibre length (mm)
PN-733	202.63	17.17	19.87	20.38	218.75	131.25	131.00	69.90	349.75	201.15	0.42	0.70
17-93-A	200.30	13.01	10.75	22.59	171.00	104.20	94.00	52.15	265.00	156.35	0.51	0.63
SE-63-016	282.23	15.13	12.07	15.06	156.25	88.48	66.25	36.41	222.50	124.88	0.51	0.68
PN-722	248.80	14.62	21.46	15.57	128.00	72.87	88.25	43.28	216.25	116.15	0.48	0.70
212/03	262.95	14.93	28.95	16.57	135.25	93.45	98.83	60.18	234.08	153.63	0.49	0.61
84/11	150.03	8.66	4.57	19.72	93.75	60.52	69.75	41.09	163.50	101.60	0.54	0.67
MB-368	246.95	14.35	17.51	13.50	185.75	89.48	138.00	73.75	323.75	163.22	0.40	0.63
PN-227	237.48	12.50	16.25	18.57	184.75	100.34	146.00	70.65	330.75	170.99	0.43	0.70
SI-64-017	273.65	17.15	16.10	19.41	233.25	136.66	161.64	85.53	394.89	222.19	0.43	0.68
NZ-1002	252.13	13.87	21.47	8.07	144.75	83.00	105.65	59.18	250.40	142.18	0.50	0.71
795	210.68	10.65	6.49	18.83	158.75	97.33	116.40	66.21	275.15	163.54	0.47	0.76
SI-63-007	252.05	12.90	12.15	12.62	143.75	95.48	102.06	58.13	245.81	153.61	0.49	0.59
V-99	219.90	9.97	9.24	10.30	149.00	79.21	111.13	61.04	260.13	140.24	0.50	0.67
NZ-1179	265.75	14.95	23.48	11.30	170.00	93.82	133.55	78.78	303.55	172.60	0.48	0.73
PN-721	221.63	12.44	11.15	15.66	123.00	79.93	127.63	77.46	250.63	157.38	0.46	0.75
131/25	216.43	12.86	14.23	17.44	183.25	108.20	142.14	81.18	325.39	189.38	0.45	0.68
799	290.35	17.39	27.90	14.59	197.00	122.72	150.49	81.45	347.49	204.17	0.42	0.77
PN-731	203.13	15.89	11.91	20.88	139.00	86.53	108.83	62.10	247.83	148.63	0.42	0.79
NZ-1040	257.55	13.74	16.98	11.53	135.00	73.12	105.01	62.28	240.01	135.40	0.46	0.77
NZ-1140	224.03	13.41	19.28	17.46	215.50	119.28	163.19	95.23	378.69	214.50	0.42	0.77
SE-75-001	164.53	8.33	6.97	6.80	136.25	66.95	106.92	59.73	243.17	126.68	0.58	0.65
NZ-1130	212.80	11.08	19.04	8.07	178.75	86.97	136.08	78.60	314.83	165.56	0.56	0.75
V-311	237.23	13.36	12.65	11.17	144.25	71.68	113.59	60.15	257.84	131.83	0.41	0.68
SE-69-002	178.30	9.42	10.95	9.16	95.50	56.78	76.50	39.87	172.00	96.64	0.57	0.72
Kashmir willow	261.65	15.92	29.81	16.72	243.25	138.94	184.05	102.87	427.30	241.81	0.46	0.81
Mean	228.55	13.21	15.92	14.87	162.55	93.48	119.10	66.28	281.62	159.77	0.48	0.71
CD (1%)	79.82	4.92	10.93	0.38	111.28	56.75	79.16	42.86	185.02	95.75	0.08	0.08
C.V(%)	18.67	19.91	36.70	1.37	36.59	32.44	35.54	34.56	35.12	32.03	8.54	5.88

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Table 3. Mean, Range, C.V. (%), GCV, PCV, heritability, genetic advance and genetic gain (%) of growth, biomass and wood characteristics

Characters	Mean	Range	C.V. (%)	Coefficient of variance			Heritability	Genetic advance (K=2.06)	Genetic gain (%)
				Genotypic	Phenotypic	Environmental			
Height (cm)	228.55	150.02- 290.35	18.67	13.42	23.00	18.66	34.07	36.87	16.13
Collar diameter (mm)	13.21	8.32-17.38	19.19	17.43	92.55	52.37	43.40	3.13	23.66
Number of branches	15.92	4.57-29.80	36.7	39.85	54.17	36.69	54.11	9.61	60.39
Shoot fresh weight (g)	162.55	93.75-243.25	36.59	15.51	39.74	36.59	15.23	20.26	12.46
Shoot dry weight (g)	93.48	56.78-138.94	32.44	18.05	37.13	32.44	23.64	16.9	18.08
Root fresh weight (g)	119.07	66.0- 184.0	35.54	17.65	39.7	35.55	19.78	19.25	16.17
Root dry weight (g)	66.28	36.40-102.90	34.56	18.52	39.21	34.56	22.31	11.94	18.02
Total green biomass (g)	281.62	163.50-427.29	35.12	15.61	38.43	35.11	19.75	44.03	15.64
Total dry biomass (g)	159.77	96.64-241.81	32.03	16.5	36.03	32.03	20.96	24.86	15.55
Wood density (g cc^{-1})	0.47	0.39-0.58	8.54	9.65	12.88	8.53	56.10	0.070	14.89
Fibre length (mm)	0.705	0.59-0.81	5.88	6.54	8.79	5.88	55.29	0.070	10.02
Leaf area (cm^2)	14.87	6.80-22.58	1.37	29.93	29.96	1.37	99.78	9.16	61.58

this lost information is kept to minimum. In the present study, three out of twelve components had given eigen value greater than unity (Table 4). These three characters are retained in further analysis as they contributed 83.49 per cent of total variation. The decision was made according to the Kaiser (1958) suggested the dropping of those principal components of the correlation matrix with eigen roots less than one.

The first component explaining 59.55 per cent including ten characters namely root fresh weight, root dry weight, shoot fresh weight, total fresh weight, total dry weight, collar diameter, shoot dry weight, number of branches, fibre length and wood density. The second component accounted for 12.60 per cent of total variation, defined by height. 11.33 per cent of the third component was defined by leaf area. Trunctaner (2002) reported five principal components on the basis of 14 traits studied in willow clones. Cumulative variability of 56 per cent from three principal components were recorded while studying on *Populus deltoides* clones (Singh, 2006). Root fresh weight, root dry weight, shoot fresh weight, total fresh weight, total dry weight, collar diameter, shoot dry weight, number of branches, fibre length and wood density are the important morphometric traits, which indicate the growth and development of plant. These may be attributed to the growth characteristics to distinct genetic constitution of the clones and their performance in given set

Table 4. Three principal components of growth, biomass and wood characteristics of 25 clones of willow

Characters	Principal components		
	I	II	III
Height (cm)	0.562	-0.688	0.284
Collar diameter (mm)	0.737	-0.595	-0.117
Number of branches	0.662	-0.428	0.417
Shoot fresh weight (g)	0.928	0.135	-0.062
Shoot dry weight (g)	0.921	0.030	-0.224
Root fresh weight(g)	0.901	0.334	0.164
Root dry weight (g)	0.870	0.366	0.208
Total green biomass (g)	0.953	0.230	0.037
Total dry biomass (g)	0.966	0.186	-0.043
Wood density (g cc^{-1})	-0.682	0.251	0.335
Fibre length (mm)	0.379	0.297	0.322
Leaf area (cm^2)	0.350	-0.010	-0.865
Eigen value	7.147	1.513	1.360
Per cent variability	59.55	12.60	11.331
Cumulative per cent variability	59.55	72.16	83.49

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of climatic and edaphic conditions (Sharma *et al.*, 2011).

The maximum weightage should be given to total dry weight (having maximum variable loading) for the selection along with other characters in first component, whereas, maximum variable loading for the shoot fresh weight and recommended the same for the selection along with other components.

CONCLUSION

Clonal forestry is meaningful only if clones used in planting are reliable. It depends on the way selection criteria used and the effectiveness of nursery testing followed by field evaluation. The situation of willow planting world over with regard to the registered clones is very bleak. A single clone *S. alba* var *coerulea* has been planted largely in U. K. for the production of cricket bats. Almost similar situation is well realized in India too with regard to genetic base of willow clones. Multiclonal plantations are desirable in willows. The concept of multiclonal varieties in individual tree mixture is very much desirable particularly in various agroforestry systems prevailing in northern part of the country. Selection of clones at juvenile age on plant height and diameter is very well in practice especially in short rotation tree species. Based on plant height, five clones were found to be promising viz., 799 (*S. matsudana X S. alba.*) followed by SE-63-016 (*S. jessoensis*), NZ-1179 (*S. matsudana X S. alba.*), 212/03 (*S. matsudana X S. caprea*) and Kashmir willow (*Salix alba*). Clone 799 and Kashmir willow registered as most promising clones on the basis of principal component analysis. Total dry weight followed by total fresh weight, shoot fresh weight and shoot dry weight are to be given maximum weightage on the basis of principal component analysis.

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Current Status of Vulture Conservation in Haryana

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Abstract: Vultures are nature's ambassador for ensuring ecological security and as quick disposal squad, they are must for the hygiene of the ecosystem. Till 1960's, vultures were found in abundance but in late 1980s, it was noticed in Keoladeo National Park of Rajasthan that there had been a considerable decline in vulture nests and by the advent of year 2000, 90% of vulture population had vanished. Sudden crash in vulture population created an emergency situation to know the cause of their death, breed them and release back into the nature. Bombay Natural History Society (BNHS) and the then Chief Wildlife Warden of Haryana took up the lead to save vultures from extinction and decided to set up a centre for vulture research. This led to the birth of world's first vulture conservation breeding centre (VCBC) at Pinjore in 2000. The scientists at this centre remained clueless for the mysterious death of vultures till 2002 but ultimately discovered that common painkiller drug diclofenac administered in domestic animals, which ultimately reached vultures via dead carcass is causing havoc by causing visceral gout and renal failure followed by their death. BNHS and Haryana Govt's efforts have led to ban on the use of diclofenac as a veterinary drug. At VCBC, three *Gyps* vulture species namely *Gyps bengalensis, G. indicus and G. tenuirostris* have been kept for research and during 13 years of the centre's existence, lot of nature's secrets related to life of vultures have been studied in captivity. The centre has succeeded in captive breeding of all vulture species. The centre plans to release first stock of birds in 2016, and the birds are being trained accordingly.

Key Words: *Gyps*, diclofenac, king vulture, BNHS, Pinjore, breeding

Vulture crisis is one of the critical ecological issues the world is facing today. From 40 billion in 1960s to just 1,20,000 in 2010. Yes, that is the estimated population of vultures left in nature. Once very common, vultures are today on the verge of extinction. This is the biggest population crash and ecological disaster after the Passenger Pigeon (*Ectopristis migratorius).* About two and half decades ago, the vultures were seen in plenty near cities, towns, villages, open areas, scrubby jungles and scattered tall trees. However in 80's, the gradual decline in vulture population was observed by the environmentalists, which assumed alarming proportion in late 80s. Today these scavenging birds are hardly seen at the places where they were seen in large numbers. The scientists world over have focused their attention to protect and preserve this important bird playing a vital role for the maintaining environment in proper health. In agrarian states like Haryana where rearing of cattle is a traditional profession and matter of pride, the vultures have more important role in the ecosystem as more number of carcasses are produced in the state.

Nature's Quick Disposal Squad

The moment the vultures come to know of the dead animal, they will come out in a group of hundreds, will do their job within minutes and fly back for a sun bath. This way they keep the nature neat and clean. They are able to reach at places where other human beings can not reach. They dispose of the carcasses of the dead wild animals in the jungle and the domestic animals outside the forests. Nature has gifted them the iron clad digestive system. They can happily eat meat in any stage of putrefaction and no toxin even putricine cannot make them sick. While they are on their job of cleaning the nature, they continuously urinate to kill the pathogens, which get on to their legs. In their absence, the carcasses are eaten by the feral dogs. Since the dead animals are generally infected with deadly pathogens, the dogs also get the disease. Thus, vultures prevent the spread of diseases like anthrax and rabies, which could play havoc to the wildlife, domestic animals and human beings. According to a recent report, as a result of vulture decline, an additional 5.5 million feral dogs have been added between 1992 and 2006. This has resulted into additional 38.5 million dog bites resulting into 47,300 deaths.

Vultures in Culture

Vultures have deep roots in Indian culture. They are the part and parcel of Indian culture. They have historical, mythological, cultural, and ecological importance.

Jatayu has great respect among Hindus. Jatayu is nothing but a vulture that lived during Ramayana period. It is said that during Ramayana period Jatayu had helped Lord Rama, Lakshmana and Sita during their exile. The story goes that when mother Sita was being forcefully taken away by Ravana, Jatayu, had spotted mother Sita in trouble from the sky top. He immediately blocked the way for Ravana. It is further said that he fought fiercely with Ravana and forced him to come down from his chariot. He fought bravely for a long time but finally Ravana succeeded to cut one of

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his wings. Jatayu fell injured and Ravana moved away. However, he did not give up and guided Rama in locating Sita in Srilanka. Thereafter, Jatayu succumbed to his injuries and died. Afterwords his brother Sampati also helped Rama in fight against evil. Having come to know of the help Jatayu had extended to Rama, which was revealed by Lord Rama himself, local people built a temple at the place of death of Jatayu. The place at present is called Jatayu Para. It is 30 km. away from Kollam in Kerala.

Gidhraj Parvat also called Gridha Kuta Parvat meaning Vulture Peak is located in village Devrajnagar of tehsil Ramnagar in Satna district of M.P. The vulture peak is located at an altitude of 2354 feet. It has been vultures preferred place for breeding and roosting. An annual fair is also organized here every year in the month of Magha on the occasion of Vasant Panchami.

Vultures and Parsi cultures are inseparable. Parsis follow Zoroastrianism. According to Zoroastrian faith, the dead bodies cannot be buried or burnt because corpses could pollute Panchabhootam (earth, water, air, space and fire). Hence, Parses leave their bodies in a high-rise 'Tower of Silence' to be consumed by the vultures.

Species, Their Distribution and Classification

The vultures are found everywhere on the earth except Australia and Antarctica. They move with thermals. Antarctica has inhospitable climate and Australia does not have thermals. The vultures have been broadly divided into two categories viz., Old World and New World Vultures. The New World Vultures belong to America and they are represented by Californian & Andean Condors. The vultures belonging to Asia, Europe, & Africa have been classified as Old World vultures. Out of 20 species nine are found in Old World. The new world vultures have olfactory canals and are able to smell, the moment they come to know of the carrion. The new world vultures lack olfactory canals and cannot smell.

India has nine species of vultures i.e., White backed vulture (*Gyps bengalensis);* Slender billed vulture (*Gyps tenuirostris);* Long billed vulture (*Gyps indicus);* Red headed vulture or King vulture or Pondicherry vulture (*Sarcogyps calvus);* Indian Griffon Vulture or Eurasian vulture (*Gyps fulvus);* Himalayan Griffon (*Gyps himalayensis);* Cinereous Vulture or Monk Vulture *(Aegypius monachus);* Bearded vulture or Lammergier vulture (*Gypaetus barbatus) and* Egyptian vulture *(Neophron percnopterus).* Except the Bearded/Lammergier vulture, all other vultures are seen in Haryana. The King vulture has wide distribution and is found throughout India. As regards *Gyps* species, *G. tenuirostris* is distributed mostly in north eastern region; *G. benghasis* has fairly wide distribution and is found in southern and central India. *G. indicus* has narrow distribution and is found in southern India. While Himalayan Griffon and Lammergier restrict their distribution in cool Himalayas, the Monk vulture too lives in Himalayas but descends to sub Himalayan region during winters. Eurasian vulture is a winter visitor and seen in Gujarat, Rajasthan and in drier parts of Haryana and Punjab adjoining Rajasthan.

Decline in vulture population: Till late eighties nobody knew that the vultures were declining. Infact in India still vultures are considered as bad omen waiting for somebody to die. So, neither anybody bothered nor anybody reported the vanishing population of vultures in the nature. It was only in late nineties, Dr. Vibhu Prakash of Bombay Natural History Society (BNHS) while studying the raptors in Keoladeo National Park of Rajasthan observed that the vultures were no longer nesting and no eggs are being laid.

Neck drooping was first observed in Keoladeo National Park by Dr. Vibhu Prakash, where birds exhibit this behaviour for over several weeks before finally collapsing and falling to death. This is behavioural indication that birds are ill.

Meanwhile an injured vulture landed up in Pinjore near Chandigarh in 2000. Local took it as Jatayu. They worshipped it and offered prayers and money. A team of scientists headed by Dr. Vibhu Prakash visited Pinjore to identify the bird on the request of chief wildlife warden Haryana, Sh. Ram Dhirendra Jakati. The bird was identified as Cinereous vulture. It was kept in Pinjore zoo and was treated for its injuries. After the bird recovered, it was released at a place called Bir Shikargah about eight kilometres from Pinjore. It is a place where the present Vulture Conservation Breeding Centre exists.

Leave *Gyps* species, at present almost all species of vulture are critically endangered. It is not in India alone, but all over the world the vultures are vanishing. So, it is not that only *Gyps* species are endangered but all vulture species are in danger. Most critical of all is the Slender Billed vulture and experts opine that there are very few Sender Billed left in the wild. Perhaps King vulture is also equally endangered. It was seen throughout Indian sub continent. But now it is rare to see King Vulture. Till two years back, it was nesting in Nepal, but since 2010, the report is not encouraging. Its nests are no longer being seen in Nepal as well.

From Vulture Care Centre to Vulture Conservation Breeding Centre (VCBC)

The Vulture Conservation Breeding Centre (VCBC), earlier known as Vulture Care Centre (VCC), was

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established in September 2001 to investigate the dramatic declines in India's *Gyps* species of vultures. It is a collaborative initiative between Bombay Natural History Society and the Haryana Forest Department, to save the three species of vultures (*Gyps bengalensis, Gups indicus* and *Gyps tenuirostris)*. The VCBC is located 8 km east of Pinjore, off the Chandigarh-Shimla highway, aims to establish a founder population of 25 pairs of each of the 3 species of vultures; produce a population of at least 200 birds of each species in 15 years to be reintroduced to the wild and release 100 pairs each of the three species of vultures in the next fifteen years.

VCBC has two quarantine aviaries or holding aviaries and each can hold 20 birds. Any bird brought to the centre is first kept in these aviaries and their health is monitored for 45 days. It has three nursery aviaries to provide a natural nest-like environment for rearing of nestlings. These aviaries can rear up to 24 nestlings at a time. Four hospital aviaries for treating injured bird and eight breeding aviaries for conservation breeding of vultures are also established. Three colony aviaries meant to house sub-adult and adult birds are also available. These aviaries are large enough for the birds to exercise by flying from one end to another and feed socially on carcasses, exactly as they do in the wild. Also two displays for education and generating awareness are also additional components at the centre.

The centre has holding aviaries with capacity to hold 10 pairs in the big aviary and 2 pairs each in the smaller ones. These aviaries house the juveniles after they fledge in nursery aviaries. The centre has a well-equipped laboratory also.

Achievements of VCBC

There are a total of 160 birds at the centre of which 62 are Oriental white-backed vultures, 75 Long-billed vultures, 21 Slender-billed vultures and 2 Himalayan Griffons. The founder stock has been collected from various states of the country viz. Assam, Haryana, Rajasthan, Gujarat, Madhya Pradesh and Maharashtra. All three *Gyps* species, the Oriental white-backed vulture, Long-billed vulture and Slender-billed vulture have been bred at the centre. This has happened the first time ever for all the three species. So far, 61 nestlings have successfully hatched and fledged at the centre. Of these, 25 are of Oriental white-backed vulture, 29 of Long-billed vulture and ten of Slender-billed vulture. This does not include the chicks that have hatched in December, 2013 January, 2014.

The pioneering work done at VCBC during 2005 in identifying a vulture safe drug, Meloxicam, in collaboration with Indian Veterinary Research Institute, Izzatnagar, which could be given to cattle and is absolutely safe for vultures is of great significance and would go a long way in saving the vultures from extinction. Meloxicam as a vulture safe alternative drug to diclofenac was successfully tested at the centre.

The centre has successfully implemented the technique of double clutching by inducing the pairs to lay again by removing the first clutch. The eggs removed are incubated in incubators. The birds lay again in about three week's time. Eggs of Oriental white-backed vulture and of Long-billed vulture have been successfully hatched in incubators.

When the cause of vulture was known, the efforts started for eliminating diclofenac from the system. The Govt. of Haryana took up the matter with Govt. of India and breakthrough came in the year 2006 when Govt. of India put a ban on the use of doclofenac for veterinary use. However, recently a NSAID named Aceclofenac has been introduced for veterinary and human use. When it goes into the system, it is metabolised into diclofenac. The detailed biochemical studies need to be conducted on this drug as it may prove equally fatal to vultures as diclifenac is.

The first batch of vultures bred at VCBC will be released into the wild in 2016. But the place of release has to be carefully chosen depending upon the best suited habitat for particular *Gyps* species. Vulture safe zones have to be identified/established and it has to be ensured that diclofenac is completely out of the system. Initially scientists were reluctant to adot the diclofenac theory but now they agree that diclofenac resulted in decline of *Gyps* and non-*Gyps* species (Green *et al*., 2004, Oaks *et al*., 2004, Shultz *et al*., 2004, Prakash *et al*., 2005; Swan *et al*., 2006). Therefore, we have to be cautious before their release.

There is no doubt that the vultures are nature's most efficient scavangers. They are the ultimate recyclers – able to strip a carcass in just an hour to keep environment clean. Vulture crisis is one of the critical ecological issues the world is facing today. They are the most endangered group of birds globally. IUCN has already placed them in critically endangered category and their removal from the ecosystem will affect the equilibrium between populations of other scavenging species. The Parsi culture is on the verge of disintegration as there are no more vultures left to dispose of a Parsi body. Not only *Gyps* species, all other species are also equally important as each species of vulture has a specific role in disposing of carrion. There is need to be vulturiphils rather than being Gypsiphils. Ban on diclofenac in only preventive. We have to think for the ways and means to reduce uric acid in vultures. There is need to generate

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mass awareness about the conservation needs of vultures on the lines of tiger. Let us do it now before it is too late. Already some initiatives have started, captive breeding efforts are ongoing in breeding centres in India (Pain *et al.*, 2008). In 2009, captive birds laid eggs, raising hopes that they will successfully breed in captivity in the near future.

CONCLUSION

There is no doubt that the vultures are the inseparable part of our ecosystem. However, they are not being given the kind of importance they deserve. Very important reason for this is that they are still treated bad, opportunistic, dirty and as if waiting for some one to die. Leave common man, there is lack of awareness about them among all sections of the society. Many learned people, elite class and even media paints bad picture about them. So, we need to sensitize all sections of the society including common man, educate elite class and even print/electronic media about the conservation needs of vultures and myths surroundings these innocent birds. Besides generating awareness, we need to focus on conservation breeding of all vulture species especially the Red headed or King vulture, which is also critically endangered. At present, the vulture conservation programme in India is being run with assistance from organizations like Darwin's Initiatives, Zoological Society of London, and Birds of Prey London etc. There is need to pump more finds for vulture research in India.

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Indian Journal of Ecology

Status of Bird Diversity in Belagavi District, Karnataka State

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Abstract: This study was conducted to determine the urban bird diversity and status in Belagavi city of Karnataka state. The study showed the presence of 37 species of birds spread over 25 families and eight orders. The study area was dominated by non-passerine birds compared to passerine birds. Out of 25 families, 15 families belonged to non-passerines, whereas, the passeriform birds consisted of ten families. The birds with omnivorous, carnivorous and insectivorous food habits were more common compared to those with specialized feeding types such as granivorous and frugivorous. Both passerine and non-passerine birds exhibited differential food choices despite being in the same environment. The per cent occurrence of resident birds was maximum compared to resident migratory and migratory birds. The overall depletion in species richness in the city area could be due to damage caused by human interference including urbanization and pollution, which might significantly affect the bird diversity.

Key Words: Passerine birds, non-passerine birds, bird diversity, feeding habit, urban birds

Bird diversity is helpful in determining the species richness, but the urban biodiversity has received very little attention from conservation biologist compared to natural and protected ecosystem. Since the biological diversity is under tremendous pressure from a variety of human activities (Bawa *et al.*, 2007), there is a need to determine the urban diversity status of birds. As the population of birds is a very sensitive indicator of degree of population in both terrestrial and aquatic ecosystem (Turner, 2003), determination of bird diversity status is a key to understand the impact of changing ecological conditions on fauna. Belagavi city is situated near the foot hills of Sahyadri mountain range of the north-western part of Karnataka and has good avian fauna. However, no information was available on species diversity of the birds in this area. The present study is an attempt to determine the urban bird diversity and status in Belagavi city.

MATERIALS AND METHODS

Belagavi has an average elevation of 2463 ft. above sea level, lying between 15° 51' N and 74° 31' E. It exhibits swift and kaleidoscopic changes in topography, vegetation and climate. The fort lake, situated at the entrance of the city, is one of the big lakes in northern part of Karnataka. This lake is not only ecological habitat for a many species of birds, but also significant to the environment of city. The lake is surrounded by area-wise gardens and historical fort. The fort surroundings have variety of plant species namely, *Bambusa bambos, Ficus benghalensis, F. racemosa, Acacia greggii, Tectona grandis, Cocos nucifera, Mangifera indica,* etc. These plants not only provide food and shelter, but also nesting sites for birds in the city. The study area was divided into ten different zones, namely, Fort lake, Gandhi nagar Central bus stop area, Court road, Ambedkar garden, Nehru Nagar, Shree Nagar garden, Mahantesh Nagar, Ashok Nagar and Fort area (Fig. 1).

A regular survey was carried out 3-4 times in a month between 6.00-10.30 and 17.00-18.30 IST from June 2012 to April 2013 encompassing monsoon, winter and summer seasons. The birds were observed using prismatic binoculars (10 × 40) and identified up to lowest possible taxonomic level with the help of field guides (Ali, 2002; Grimmett *et al.*, 1998). Feeding guilds were classified on the basis of direct observations and available literatures. The common names were assigned according to Manakadan and Pittie (2001). The percentage occurrence of birds was calculated.

RESULTS AND DISCUSSION

This study recorded the presence of 37 species of birds spread over 25 families and eight orders (Table 1). Passeriformes is generally known as the largest and most diverse commonly recognized clade of birds. The dominance of passerine birds was reported in the Arki hills region of Himachal Pradesh (Thakur *et al.*, 2010), the Tawa reservoir and its surrounding areas at Hoshangabad district of Madhyapradesh (Joshi and Shrivastav, 2012), and in Katgal region of Western Ghats, Uttara Kannada district (Bhat and Ganesh, 2014). However, the present study documented highest percentage of non-passerines (59.46%) compared to Passeriform (40.54%) birds (Fig. 2). Most populations of non-passerine birds comprised of Ciconiiformes (27.1%), Columbiformes (8.1%), Coraciiformes (8.1%), Charadriiformes (5.4%), Cuculiformes (5.4%), whereas, orders Strigiformes (2.7%) and Anseriformes (2.7%) were infrequent (Fig. 2). Similar

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Table 1. Checklist of birds observed at Belagavi city

	Common name	Scientific name	Status*	
			Habitat	Food
PASSERIFORMES				
Pycnonotidae	Red-vented bulbul	*Pycnonotus cafer*	R	F
	Red-whiskered bulbul	*Pycnonotus jocosus*	R	O
Sturnidae	Common myna	*Acridotheres tristis*	R	O
	Brahminy starling	*Sturnus pagodarum*	R	O
Dicruridae	Black drongo	*Dicrurus macrocercus*	R	I
Corvidae	Jungle crow	*Corvus macrorhynchos*	RM	O
	House crow	*Corvus splendens*	R	O
Motacillidae	Yellow wagtail	*Motacilla flava*	RM	I
	Large pied wagtail	*Motacilla maderaspatensis*	R	O
Muscicapidae				
	Oriental magipie robin	*Copsychus saularis*	R	I
	Jungle babbler	*Turdoides striatus*	M	I
Passeridae	House sparrow	*Passer domesticus*	R	O
Zosteropidae	White eye	*Zosterops palpebrosus*	RM	O
Daniidae	Rufous backed shrike	*Lanius schach*	R	C
Cisticolidae	Ashy prinia	*Prinia socialis*	R	I
CICONIIFORMES				
Laridae	Little tern	*Sterna albifrons*	R	C
Scolopacidae				
	Common sandpiper	*Actitis hypoleucos*	RM	O
	Wood sandpiper	*Tringa glareola*	M	C
Accipitridae	Brahminy kite	*Haliastur indus*	R	C
Threskiornithidae	Oriental white ibis	*Threskiornis melanocephalus*	M	C
Ardeidae				
	Cattle egret	*Bubulcus ibis*	RM	I
	Little egret	*Egretta garzetta*	R	C
	Median egret	*Mesophoyx intermedia*	RM	C
	Little green heron	*Butorides striatus*	R	C
	Indian pond-heron	*Ardeola grayii*	R	C
COLUMBIFORMES				
Columbidae				
	Blue rock pigeon	*Columba livia*	R	G
	Little brown-dove	*Streptopelia senegalensis*	RM	G
CORACIIFORMES	Spotted dove	*Streptopelia chinensis*	R	G
Meropidae				
Cerylidae	Small bee-eater	*Merops orientalis*	R	I
Halcyonidae	Lesser pied kingfisher	*Ceryle rudis*	R	C
CUCULIFORMES	White-breasted kingfisher	*Halcyon smyrnensis*	R	C
Cuculidae				
Centropodidae	Asian koel	*Eudynamys scolopacea*	R	O
CHARADRIIFORMES	Greater coucal	*Centropus sinensis*	R	C
Recurvirostridae				
Charadridae	Black-winged stilt	*Himantopus himantopus*	R	C
STRIGIFORMES	Red-wattled lapwing	*Vanellus indicus*	R	C
Strigidae				
ANSERIFORMES	Spotted owlet	*Athene brama*	R	C
Anatidae				
	Spot-billed duck	*Anas poecilorhyncha*	RM	O

*Abbreviations
R-Resident; M-Migratory; RM-Resident migratory; O-Omnivorous; C-Carnivorous; G-Granivorous; I-Insectivorous; F-Frugivorous.

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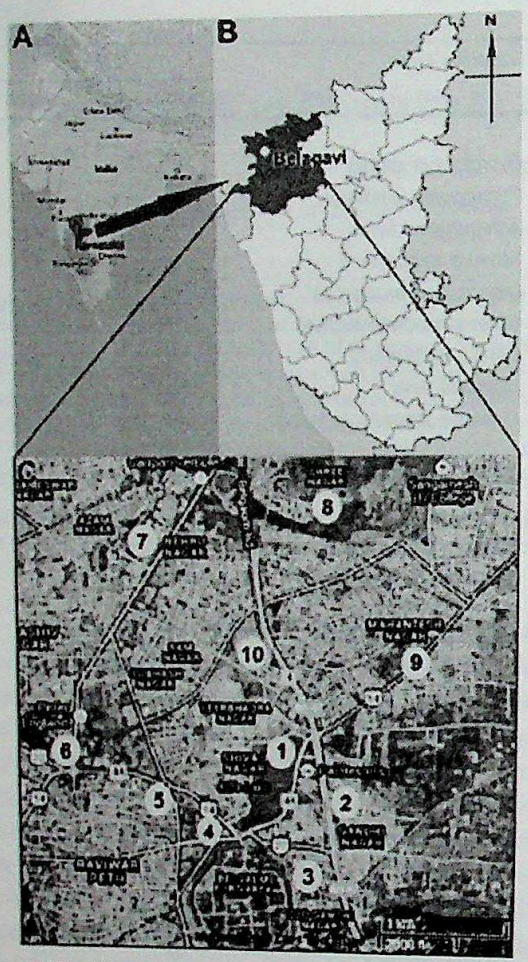

Fig. 1 (A - C). Map showing locating of Karnataka state (A), Belagavi district (B) and different zones of the study area (C).

1. Fort Lake
2. Gandhi Nagar
3. Fort Region
4. Central bus stand region
5. Court Road
6. Ambedkar Garden
7. Nehru Nagar
8. Shree Nagar Garden
9. Mahantesh Nagar
10. Ashok Nagar

dominance of non-passerine birds over passeriform birds was observed in Karnaphuli River delta and adjacent areas of Chittagong, Bangladesh (Ahsan and Hannan, 2002) and in Kurugodu, an area, which was close to mining activities at Bellary District, Karnataka (Konkal and Ganesh, 2014). However, Jose and Zacharias (2003) found almost equal distribution of passerine (56 species) and nonpasserine (55 species) birds in Calicut University campus at Kerala. These observations suggest that the species richness of specific families depend on their interactions with the local environment and vary depending on the ecological conditions.

In the present study, highest percentage of birds showed carnivorous (40.54%) followed by omnivorous (29.72%) and insectivorous (18.91%) feeding types (Fig. 3). The birds with feeding habits such as granivorous (8.10%) and frugivorous

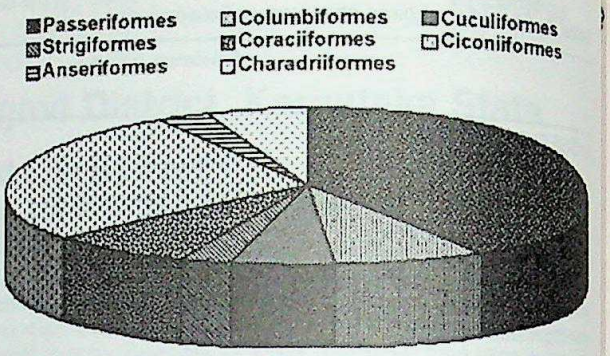

Fig. 2. Per cent occurrence of birds belonging to different orders

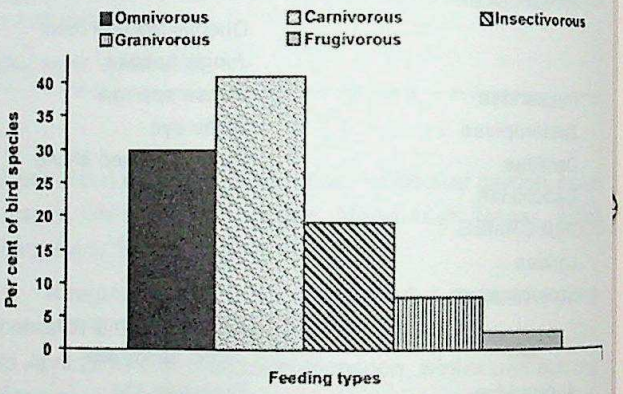

Fig. 3. Distribution of birds according to their feeding types in the study area

(2.70%) were less frequent (Fig. 3). These observations suggest that the bird population in the study area mainly rely on carnivorous and omnivorous feeding types as these adaptations enable them to feed on variety of food types. Jayson and Sivaperuman (2005) reported dominance of birds with omnivorous feeding habit, wherein out of 66 omnivorous birds, 58 species belonged to Charadriiformes followed by five species of Passeriformes at Thrissur District, Kerala. Konkal and Ganesh (2014) found that omnivorous (50%) and insectivorous (43.75%) feeding habits were dominated by the passerine birds, whereas, most of non passerine birds had carnivorous (47.36%) followed by omnivorous (19.4%) feeding habit. In the present study, most of the passerine birds exhibited omnivorous (53.33%) followed by insectivorous (33.33%), carnivorous and frugivorous (each 6.66%) feeding types. On the other hand, majority of the nonpasserine birds showed carnivorous (63.63%), followed by omnivorous and granivorous (each 13.63%) and insectivorous (9.09%) feeding types. None of the passerines and nonpasserines showed granivorous and frugivorous feeding habits respectively. These observations suggest differential feeding choices of passerines and non-passerines despite the same ecological conditions in the study area.

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The occurrence of resident birds was maximum (72.97%) compared to resident migratory (21.63%) and migratory birds (5.40%). Among Passeriformes, the Jungle barblers (Muscicapidae) were exclusive to monsoon, whereas, Ciconiiformes members such as Wood sandpiper (Scolopacidae) and Oriental white ibis (Threskiornithidae) were seen during summer and winter, respectively. Some birds such as Jungle crow, Yellow wagtail, White eye, Common sandpiper, Cattle egret, Median egret, Little brown dove and Spot-billed duck were observed as resident migratory birds within the study area.

The present study suggests a general depletion in the species richness as shown by the presence of only few members in most families, which could be due to damage caused by human interference including urbanization and pollution that might affect the bird diversity of the Belagavi city. In view of this, there is an immediate need to take necessary precautions to prevent the habitat loss. Besides, plantation of more trees in and around the city might help restoring the natural habitats, thereby bird diversity.

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Studies on Genetic Divergence in Karanj (*Pongamia pinnata*) Germplasm Collected from Haryana, Punjab and Rajasthan

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Abstract: Karanj mature pods were collected from the three states viz. Haryana, Punjab and Rajasthan in two consecutive years 2009 and 2010. Intra-cluster average D^2 value of cluster V was minimum (1.238) thus revealed the minimum genetic diversity and cluster IV had maximum (2.471), which indicated the existence of maximum genetic diversity. The average inter cluster D^2 value between cluster IV and V was maximum (7.176), whereas, the minimum inter-cluster average D^2 value was in cluster I and V (2.514). The genotypes which had highest cluster means and showed higher inter-cluster divergence with several other characters would be considered as putative parents for hybridization. Hybridization among genotypes of the same cluster may not provide a good scope for obtaining useful segregates.

Key Words: Genetic divergence, *Pongamia pinnata, Karanj,* inter and intra-clusters, variation

The extent of genetic diversity in a crop forms the basis for its genetic improvement. Therefore, the information on presence of genetic diversity is an essential prerequisite for developing superior progenies through hybridization program by using statistical tools. It is now possible to quantitatively measure the genetic divergence between two or more populations and the relative contribution of individual characters to the total divergence in such comparisons. Such studies have been very useful for hybridization in crop plants. *Pongamia pinnata* (L.) Pierre belongs to family Fabaceae (Papilionoideae) and locally know as karanj, karanja or sukhchain. It is native tree of India and available along coasts and riverbanks throughout the Indian plains. Its lateral roots have dense network which helps in controlling soil erosion and binding the sand dunes. Large seeds of this medium sized tree contain up to 40% non-edible oil (Natanam *et al.*, 1989; Nagaraj and Mukta, 2004). This tree species have diverse medicinal values as roots, bark, leaves, sap and flowers have been used in traditional medicine by the tribal practitioner/ vaidya. This tree is also useful in green manuring, as a small timber and fuel wood tree and used as fish poison, in tanning and soap industry. The extracts from various parts are known to have diverse properties viz. medicinal, insecticidal, nematicidal and pesticidal (Baswa *et al.*, 2001; Latha *et al.*, 2001; Chauhan and Chauhan, 2002; Carcache-Blanco *et al.*, 2003; Srinivasan *et al.*, 2003; Ahmed *et al.*, 2004; Alam *et al.*, 2004; Li *et al.*, 2006). The species bearing oily seeds (TBOs) with high seed oil content and ability to grow under harsh and diverse climatic conditions makes this species most suitable to meet the domestic needs of biodiesel as large area in the form of waste lands are available in our country to raise the plantations. *Pongamia pinnata* (L.) Pierre is the most promising tree species capable of producing large quantity of oil seeds for extraction of biodiesel.

Systematic research efforts for the improvement of characters like seed yield and oil content in *P. pinnata* are lacking, information regarding variation in seed yield and its oil content across agro-climatic zones is also scanty. Hence, before going for the plantations of *P. pinnata* on large scale, it is very important to identify its promising seed sources from various agro-climatic zones for ensuring high seed yield, oil content and good storability. Due to its high economic, medicinal and ecological value, systematic research work carried out to find the variation in morphological traits of seeds/ pods in three important states namely Haryana, Punjab and Rajasthan.

MATERIAL AND METHODS

The research material of Karanj was collected from the three states viz. Haryana (Ambala, Bhiwani, Jhajjar, Karnal, Kurukshetra, Panipat, Rewari and Yamuna Nagar districts), Punjab (Fatehgarh Sahib, Ferozpur, Jalandhar, Ludhiana, Patiala, and Sangrur districts) and Rajasthan (Banswara, Dungarpur, Pratapgarh, Rajsamand and Udaipur districts) located under five distinct agro-climatic zones and two agro-ecological regions (Ghosh,1991, Sehgal *et al.*, 1992) The experimental material for achieving the objectives of this study comprised of the mature pods collected from the mature trees with an average age of 15 years. Ten mature trees were selected (with average age of 15 years) from each agro-climatic zone, in February, 2009 (Table 1). The

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mature and ripened pods from 50 selected trees were collected in the month of April and May for two consecutive years 2009 and 2010.

All the pods of the selected trees were harvested individually to estimate the seed yield from each tree. The sampling method as suggested by Schmidt (2000) was used for recording the seed yield. Observations on seed weight/pod (g), 100-pod weight (g), number of seeds/100 pods, yield/plant (kg), pod length (mm), pod breadth (mm), seed length (mm), seed breadth (mm) and total oil content were recorded. The multivariate diversity (Mahalanobis, 1936) was analysed for appropriate interpretation of results.

RESULTS AND DISCUSSION

The cluster analysis is commonly used for studying the genetic divergence and for forming core subset for grouping accessions with similar characteristics into homogenous categories. Among several methods of multivariate analysis, Mahalanobis D^2 statistic and Euclidean cluster analysis has been found to be very useful in selecting parents for hybridization that will meet the specific objectives of the crop improvement program. One of the important aspects of the present investigation was to classify 50 trees into different clusters based on the genetic distances (Table 2-4). This aspect is important in the sense that in long run it will help to avoid repetition of genetically similar genotypes in hybridization programs and these objectives were achieved by assignment of these genotypes into groups and studying their intra as well as inter-group diversity. The entire population of *P. pinnata* selected for the present study were grouped into eight clusters. The cluster VI was the largest group comprising of 11 trees and second largest groups of trees were cluster I and II comprising of 7 trees each. Cluster VII and VIII had six trees each, whereas, each of the clusters III and IV included five test trees. Cluster V comprising of only three sources was the smallest group. Average intra- and inter-cluster D^2 values in table 3 indicated that intra-cluster average D^2 value of cluster V was minimum (1.238) thus recording the minimum genetic diversity among its constituents. The intra-cluster average D^2 value of cluster IV was maximum (2.471), which indicated the existence of maximum genetic diversity among its constituents. The intra-cluster average D^2 values of cluster II (2.215), cluster VII (2.030), cluster III (1.958), cluster VI (1.883), cluster I (1.723) and cluster VIII (1.461) revealed sizable genetic diversity among the genotypes. The average inter cluster D^2 value between cluster IV and V was maximum (7.176) which revealed maximum genetic divergence between these two clusters followed by cluster III and IV (6.699), cluster I and IV (5.760), cluster II and V (5.342), cluster V and VIII (4.865) and cluster III and VII (4.725). The minimum inter-cluster average D^2 value was found between the cluster I and V (2.514) followed by cluster II and VI (2.668) and cluster VI and VIII (2.680). Cluster III had the lowest cluster mean for seed weight per pod, 100-pod weight, 100-seed weight, breadth of seeds and oil content while cluster IV recorded maximum cluster mean for seed weight per pod, 100-pod weight, 100-seed weight, pod breadth, seed length, seed

Table 1. Agro-climatic zones surveyed for the collection of germplasm

S.No.	Name of agro-climatic zone	Name of agro-ecological region
1	HR-1 (Eastern Zone, Haryana)	Trans Gangetic Plain Region
2	HR-2 (Western Zone, Haryana)	-do-
3	PB-3 (Central Plain Zone, Ludhiana, Punjab)	-do-
4	RJ-7 (Sub Humid Southern Plain and Aravalli Hill Zone, Udaipur, Rajasthan)	Central Plateau and Hill Region
5	RJ-8 (Southern Humid Plain Zone, Banswara,Rajasthan)	-do-

Table 2. Distribution of different test trees of *P. pinnata* in clusters based on D^2 statistics

Clusters	No. of trees/ genotypes	Details of test trees/genotypes
I	7	RJ-7/7,RJ-7/8,RJ-7/10,RJ-8/1,RJ-8/7,HR-1/7,HR-2/2
II	7	HR-1/1,HR-1/2,HR-1/10,HR-2/1,HR-2/9,PB-3/4,PB-3/6
III	5	HR-2/10,PB-3/1,PB-3/2,PB-3/3,PB-3/5
IV	5	RJ-7/2,RJ-7/3,RJ-7/9,RJ-8/6,RJ-8/10
V	3	RJ-7/1,RJ-8/2,RJ-8/9
VI	11	RJ-7/5,RJ-8/3,HR-1/3,HR-1/6,HR-1/9,HR-2/3,HR-2/7,PB-3/7,PB-3/8,PB-3/9,PB-3/10
VII	6	RJ-7/4,RJ-7/6,RJ-8/5,RJ-8/8,HR-2/6,HR-2/8
VIII	6	RJ-8/4,HR-1/4,HR-1/5,HR-1/8,HR-2/4,HR-2/5

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Table 3. Average inter- and intra-cluster distance (D^2) among eight clusters of *P. pinnata*

Clusters	I	II	III	IV	V	VI	VII	VIII
I	1.723							
II	3.341	2.215						
III	2.722	3.767	1.958					
IV	5.760	3.849	6.699	2.471				
V	2.514	5.342	4.084	7.176	1.238			
VI	3.119	2.668	3.098	4.690	4.256	1.883		
VII	3.069	2.786	4.725	3.626	4.138	3.214	2.030	
VIII	3.429	2.865	4.288	3.310	4.865	2.680	2.963	1.461

breadth and oil content indicating that these genotypes have poor performance (Table 4). The cluster VI had highest cluster mean for number of seeds per 100 pods and lowest cluster mean for pod length. Cluster VII had highest cluster mean for pod length, while cluster II recorded lowest cluster mean for number of seeds per 100 pods and seed yield per plant. The cluster V had the lowest cluster mean for pod breadth and seed length but highest cluster mean for seed yield per plant. The genotypes, which had highest cluster means and showed higher inter-cluster divergence with several other characters can be considered as putative parents for hybridization. Since the hybridization among genotypes of the same cluster may not provide a good scope for obtaining useful segregates, the putative parents for hybridization program should thus belong to different diverse clusters with high cluster means for the yield components as selection criterion. At the same time, *per se* performance of the constituents of diverse clusters should also be considered for selection as parents. The parentage of 50 trees included in the present study indicated that the genotypes, which belong to different eco-geographical areas were observed to be included in the same cluster and genotypes from different agro-climatic zones/ eco-geographical areas were included in the same cluster, which indicated that there is no association between clustering pattern and eco-geographical distribution of the trees. Bhat (1970) had also reported that eco-geographical diversity is not necessarily related to genetic diversity. Also, the clustering of genotypes from different eco-geographical locations into one cluster could be attributed to the possible free exchange of breeding materials or even species from one place to another. It may also be due to the fact that the unidirectional selection practiced for a particular trait in several places produced similar phenotypes which were aggregated in one cluster irrespective of their distant geographic origin (Somayajulu *et al.*, 1970). On the other hand, many species originating from one place were scattered over different clusters. Such genetic diversity among the genotypes of common geographic origin could be due to the factors like heterogeneity, genetic architecture of the populations, past history of selection, developmental traits and degree of general combining ability (Murty and Arunachalam, 1966). This fact is also supported by wide inter-cluster differences among them. This situation, however, helps the investigator to arrive at a very important conclusion that the grouping based on total D^2 analysis can be relied upon only when the characters of major importance like pod length, 100-seed weight, total seedling length, early vigor and storage behavior are taken into consideration. Similar results for cluster assignment of different genotypes of *P. pinnata* have been reported by Hooda *et al.* (2009) and Divakara *et al.* (2010).

Table 4. Cluster mean values for various pod and seed traits of *P. pinnata*

Clusters	Seed weight pod^{-1} (g)	100 pod weight (g)	No of seeds/ 100 pods	100 seed weight (g)	Yield plant^{-1} (kg)	Pod length (mm)	Pod breadth (mm)	Seed length (mm)	Seed breadth (mm)	Oil content (%)
I	1.17	264.33	117.14	112.46	23.05	50.19	21.95	19.76	14.86	38.80
II	1.53	359.48	114.76	150.06	13.57	52.05	24.72	22.57	16.10	34.97
III	0.99	273.07	124.87	97.80	17.00	49.66	26.73	18.07	14.73	33.12
IV	1.99	420.53	124.07	194.19	25.20	57.93	27.13	23.53	17.60	42.16
V	1.15	244.78	139.00	103.80	26.67	49.89	19.33	17.89	12.89	41.31
VI	1.45	325.76	146.58	129.42	13.61	49.30	25.30	20.15	16.18	37.40
VII	1.57	340.05	127.06	149.20	20.06	58.66	21.67	22.28	15.11	41.31
VIII	1.62	340.11	134.72	145.14	31.17	51.56	25.17	21.61	17.22	37.71

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Congruence of Random Amplification of Polymorphic Deoxyribonucleic Acid and Simple Sequence Repeats Markers in Genetic Characterization of Willow (*Salix* Spp.)

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Abstract: Genetic characterization of 94 genotypes (4 female, 10 male, and 80 half sibs) of *Salix* were analyzed using 10 SSRs and 15 RAPDs PCR-based molecular markers. RAPD analysis yielded 87 polymorphic fragments (98.9%), with an average of 5.8 polymorphic fragments per primer. Similarly, SSR analysis produced 33 bands, out of which 26 were polymorphic (78.8%) with an average of 2.6 polymorphic fragments per primer. The genetic diversity was high among the genotypes (Nei's genetic diversity = 0.354 and Shannon's information index = 0.536) as measured by combination of both RAPD and SSR markers. The mean coefficient of gene differentiation (Gst) was 0.037, indicating 96.6% of the genetic diversity resided within the genotypes. It was found that the genetic diversity among genotypes was broader, suggesting the importance and feasibility of introducing elite genotypes from different hybrids for willows germplasm conservation and breeding programs.

Key Words: *Salix sp.*, half sibs, molecular markers, genetic diversity, RAPD, SSR

There are more than 300 *Salix* species, and they are widespread in both the Northern and the Southern hemispheres, excluding Australasia and New Guinea. Willows are dioecious but may reproduce as well sexually as by vegetative propagation. The willows are typical tree-forming pioneer species in alluvial plains and riparian zones. The delimitation between these polyploid taxa relies on relatively few diagnostic features in the morphology. Consequently, large overlaps exist, which make it difficult to identify samples from the field unambiguously. In many cases, the two species coexist in mixed stands. Artificial hybridization is possible, but the taxonomic identity as well as the identification of their metapopulations remains difficult. Different elements such as the lack of qualitative diagnostic characters, the frequent occurrence of intermediate morphological forms and the successful interspecific controlled crosses support the hypothesis that *S. alba* and *S. fragilis* may hybridize frequently in nature (Triest *et al.*, 2000). *S. viminalis* L. and *S. schwerinii* E. Wolf are dioecious willows that are phenotypically very similar. Both are multi-stemmed shrubs with long and slender leaves and are commonly found along streams and rivers and in other wet areas. As other *Salix species*, the sex-ratio is often female biased (Ueno *et al.*, 2007). In *S. sachalinensis*, for example, clonal propagation was less important than expected. *S. viminalis* has a vast natural distribution ranging from Ireland and United Kingdom in the west to Siberia in the east. The exact boundaries of the natural range in Western Europe are uncertain due to extensive cultivation in the past.

A number of problems have been highlighted, including a largely undefined genetic pool of clonal lines, which can be used as progenitors in a breeding programme and limited information on the genetic basis of many agronomically important traits. Within the last twenty years, molecular biology has revolutionized conventional breeding techniques in all areas. Biochemical and molecular techniques have shortened the duration of breeding programs from years to months, weeks, or eliminated the need for them all together. The use of molecular markers in conventional breeding techniques has also improved the accuracy of crosses and allowed breeders to produce strains with combined traits that were impossible before the advent of DNA technology. Many of the willow cultivars exploited for biomass production are closely related genetically and can be difficult to distinguish using traditional morphological criteria. The objective of this study was to compare the effectiveness of both the PCR-based molecular approaches to determine the genetic relationships among several genotypes of willows parents and their hybrids.

MATERIALS AND METHODS

Ninety four genotypes (eighty half sib, four female and ten male) of *Salix sp.* were collected from Naganji nursery farm of the Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) India, (Table 1). Although these plants showed distinctive taxonomic traits of the different willow species, they were chosen for their great variability in terms of morphological traits such as young

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and mature leaves, bark colour etc. The detailed methodology including the list of primers used for RADP/ SSR, GC content, total number of loci, the level of polymorphism, resolving power and PIC value are same as followed by Singh *et al.* (2013)

RESULTS AND DISCUSSION

A total of 94 plant samples were fingerprinted using 15 RAPD makers. These primers produced multiple band profiles with a number of amplified DNA fragments varying from 4 to 7. All the amplified fragments varied in size from 100-2000 bp. Out of 88 amplified bands, 87 were found polymorphic (98.8%). The observed high proportion of polymorphic loci suggests that there is a high degree of genetic variation in the *Salix spp.* The resolving power of the 15 RAPD primers ranged from 5.471 for primer OPJ-10 to a maximum of 8.471 for primer OPJ-2. Polymorphism information content (PIC) refers to the value of a marker for detecting polymorphism within a population or set of genotypes by taking into account not only the number of alleles that are expressed but also the relative frequencies of alleles per locus. As evident, RAPD marker 'OPJ-2' showed the highest level of polymorphism with PIC value of 0.795, whereas, the PIC values for the rest of the RAPD markers were in the range of 0.713 to 0.791. A dendrogram analysis based on bootstrapping and neighbor joining (NJ) method grouped all the 94 genotypes into 3 main clusters which are further extensively divided into mini clusters (Figure 1a). Similarly, an unbiased clustering of genotypes based on STRUCTURE program without prior knowledge about the populations, clustered all the 94 genotypes into three major clusters. Under the admixed model, STRUCTURE calculated that the estimate of likelihood of the data i.e. ΔK reached its maximum value when $K = 3$ (Figure 1b [A]), suggesting that all the populations fell into one of the 3 clusters albeit small interference (Figure 1b[B]). This result is almost similar to the splitting in the NJ tree. Overall the cluster analysis strongly suggested that the 94 sampled genotypes can be divided into 3 clusters, however, there is no distinct clustering of genotypes based on their 4 female, 10 male, and 80 half sibs.

The genetic diversity of 94 genotypes was calculated in terms of Na, Ne, H, I, Ht, and PPL with respect to 3 different groups such as 4 female, 10 male, and 80 half sibs revealed higher values, indicating more variability among the genotypes (Table 2). Polymorphic loci of 100% was calculated using POPGENE among 4 females, 10 males, and 80 half sibs genotypes. Three groups containing genotypes with different sexes such as female, half sibs and males showed Nei's genetic diversity (H): 0.390, 0.412 and 0.398, respectively and of Shannon's information index (I): 0.563, 0.601 and 0.583 (Table 2), respectively showed a

Table 1. List of the 94 *Salix* genotypes

Female	Half sibs	Half sibs	Half sibs	Half sibs	Male
Salix tetrasperma	Half sib 1	Half sib 21	Half sib41	Half sib61	*Salix alba*
Salix matsudana x Salix alba (J7990)	Half sib 2	Half sib22	Half sib42	Half sib62	*Salix babylonica*
Salix matsudana (PN227)	Half sib 3	Half sib23	Half sib43	Half sib63	*Salix tetrasperma*
Salix matsudana (SE-69-002)	Half sib 4	Half sib24	Half sib44	Half sib64	*Salix matsudana* (PN722)
-	Half sib 5	Half sib25	Half sib45	Half sib65	*Salix rubence*
-	Half sib 6	Half sib26	Half sib46	Half sib66	*Salix udensis* (SX59)
-	Half sib 7	Half sib27	Half sib47	Half sib67	*Salix alba X Salix babylonica* (131/25)
-	Half sib 8	Half sib28	Half sib48	Half sib68	*Salix matsudana X Salix alba* (NZ1140)
-	Half sib 9	Half sib29	Half sib49	Half sib69	*Salix matsudana X Salix alba* (NZ1179)
-	Half sib 10	Half sib30	Half sib50	Half sib70	*S.matsudana X S.alba* (NZ1002)
-	Half sib11	Half sib31	Half sib51	Half sib71	-
-	Half sib12	Half sib32	Half sib52	Half sib72	-
-	Half sib13	Half sib33	Half sib53	Half sib73	-
-	Half sib14	Half sib34	Half sib54	Half sib74	-
-	Half sib15	Half sib35	Half sib55	Half sib75	-
-	Half sib16	Half sib36	Half sib56	Half sib76	-
-	Half sib17	Half sib37	Half sib57	Half sib77	-
-	Half sib 18	Half sib38	Half sib58	Half sib78	-
	Half sib 19	Half sib39	Half sib59	Half sib79	-
	Half sib20	Half sib40	Half sib60	Half sib80	-

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Table 2. Summary of genetic variation statistics RAPD, SSR and combination of both RAPD and SSR profiling among the genotypes of *Salix sps* grouped according to sex.

	Sample size	Na	Ne	H	I	Ht	NPL	PPL
RAPD markers								
Male	10	2.00	1.698	0.398	0.583	0.398	61	100
		(0.00)	(0.234)	(0.094)	(0.108)	(0.009)		
Half sibs	80	2.00	1.720	0.412	0.601	0.412	61	100
		(0.00)	(0.178)	(0.065)	(0.071)	(0.004)		
Female	4	1.917	1.697	0.390	0.563	0.390	60	91.67
SSR Marker								
Male	10	2.00	1.561	0.351	0.533	0.351	59	100
		(0.00)	(0.174)	(0.074)	(0.086)	(0.005)		
Half sib	80	2.00	1.389	0.278	0.450	0.278	59	100
		(0.00)	(0.070)	(0.036)	(0.045)	(0.001)		
Female	1.983	1.677	0.396	0.581	0.396		58	98.33
	(0.129)	(0.188)	(0.073)	(0.094)	(0.005)			
Combination of RAPD and SSR markers								
Male	10	2.00	1.629	0.375	0.558	0.375	120	100
		(0.00)	(0.217)	(0.088)	(0.100)	(0.008)		
Half sibs	80	2.00	1.555	0.345	0.526	0.345	120	100
		(0.00)	(0.214)	(0.085)	(0.096)	(0.007)		
Female	4	1.950	1.687	0.393	0.572	0.393	114	95
		(0.219)	(0.240)	(0.107)	(0.144)	(0.011)		

Na, Observed number of alleles; Ne, Effective number of alleles; H, Nei's gene diversity; I, Shannon's Information index; Ht Heterozygosity; NPL, Number of polymorphic loci; PPL, Percentage of polymorphic loci

higher genetic differentiation within each of the three groups. The respective values for overall genetic variability for Na, Ne, H, I, Ht, Hs, Gst, NPL, PPL and Gene flow (Nm) across all the 94 genotypes were also given in Table 3. The rate of gene flow estimated using Gst value (70.93) was found to be very high. Analysis of molecular variance among genotypes based on three major groups with respect to 4 female, 10 male, and 80 half sibs plant indicated that majority of genetic variation (99.53%) occurred among genotypes, while the variation between the three groups was minimum (0.50%) (Table 4).

SSR analysis: The 10 SSR primers selected in the study generated a total of 33 SSR bands (an average of 3.3 bands per primer), out of which 26 were polymorphic (78.8%). Among the dinucleotide repeat types (AG)n and (GA)n were produced more number of bands followed by (CT)n, and (AC)n. Similarly among the tri-nucleotide repeat types, (CTC)n produced more number of bands. The primers that were based on the (GA)n, (AG)n and (CT)n motif produced more polymorphism than the primers based on any other motifs used in the present investigation. We obtained good amplification products from primers based on (AG)n and (GA)n repeats, despite the fact that (AT)n di-nucleotide repeats are thought to be the most abundant motifs in plant species (Martin and Sanchez-helamo , 2000). A possible explanation of these results is that SSR primers based on AT motifs are self-annealing, due to sequence complementarity, and would form dimers during PCR amplification (Blair *et al.*, 1999) or it may be due to its-non annealing with template DNA due to its low Tm. The resolving power (Rp) of the 10 SSR primers ranged from 2.118 to 6.882 (Singh *et al.*, 2013). Similarly the PIC value ranges from 0.105 to 0.777 demonstrating uniform polymorphism rate among all the 10 SSR primers.

The complete data set of 723 bands was used for cluster analysis based on bootstrapping and NJ method. The genotypes were clustered into three major clusters, well supported by bootstrap value of > 20 (Figure 2a). The estimated likelihood of the clustering of data using structure was found to be optimal i.e. ΔK reached its maximum value when K = 3 (Figure 2b[A]), suggesting that all the populations were distributed with high probability into one of the 3 clusters (Figure 2b[B]). The clustering pattern of the genotypes were almost similar to the splitting in the NJ tree, however, there is no distinct clustering of genotypes based on their 4 female, 10 male, and 80 half sibs plants.

A relatively high genetic variation was detected among the genotypes categorized into 3 different groups. Genetic

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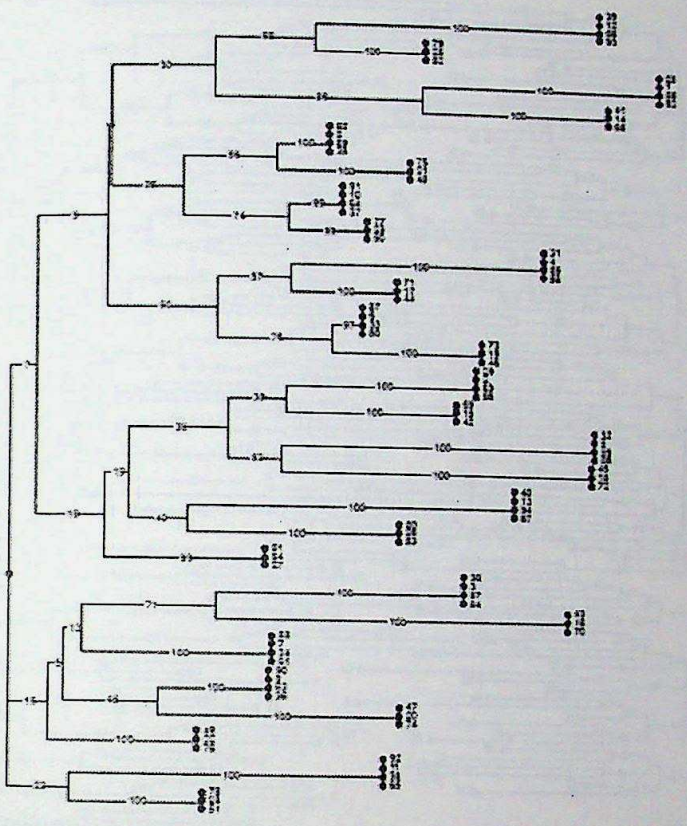

Fig. 1a. Dendrogram generated by Neighbor joining (NJ) clustering technique showing relationships between 94 genotypes of *Salix* based on RAPD profiling. Number indicates bootstrap support values.

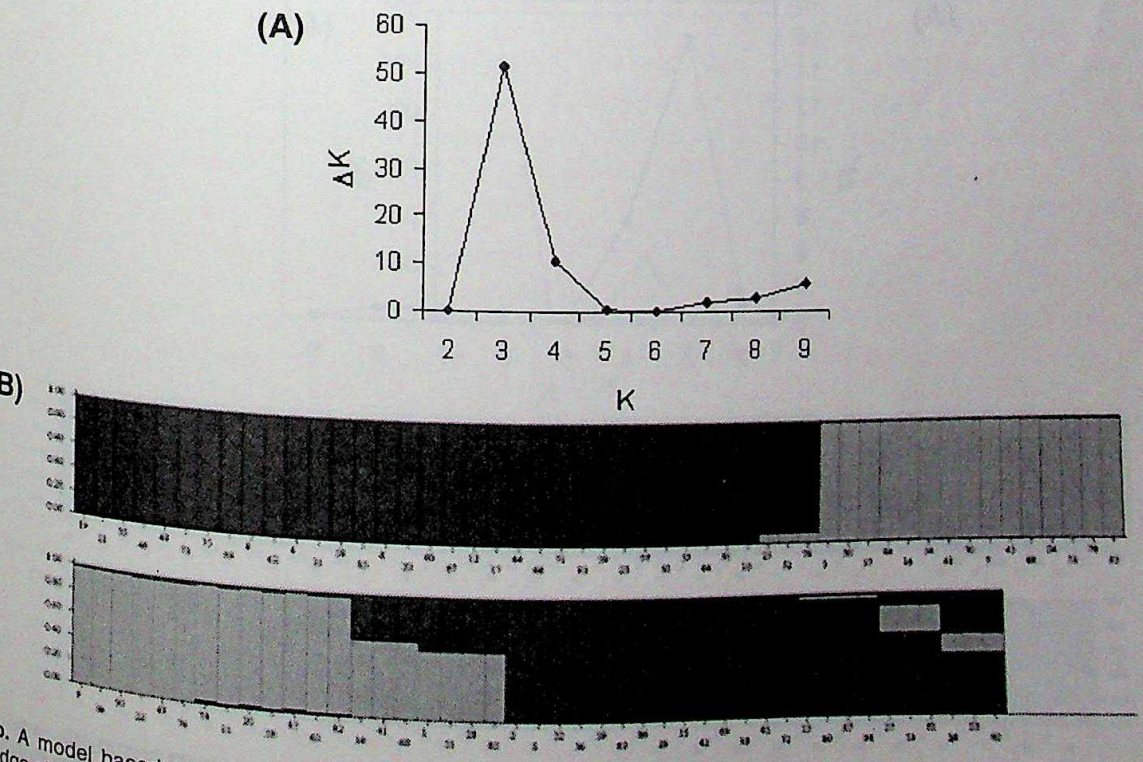

Fig. 1b. A model based clustering of 94 genotypes of *Salix sps* based on RAPD profiling and using STRUCTURE without prior knowledge about the populations and under an admixed model. (A) The relationship between K and ΔK., i.e. ΔK is reaches its maximum when K = 3, suggesting that all genotypes fall into one of the 3 clusters. (B) Grouping of genotypes when K = 3. The genotypes were more likely clustered with respect to one of the 3 clusters. Genotypes from different clusters are represented with different colours.

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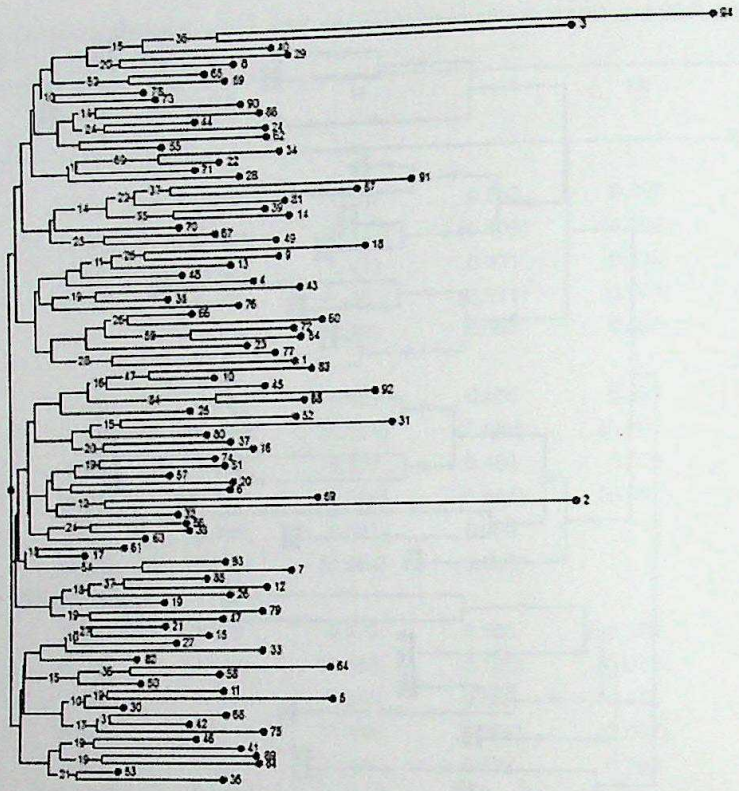

Fig. 2a. Dendrogram generated by Neighbor joining (NJ) clustering technique showing relationships between 94 *Salix* genotypes based on SSR profiling. Number indicates bootstrap support values.

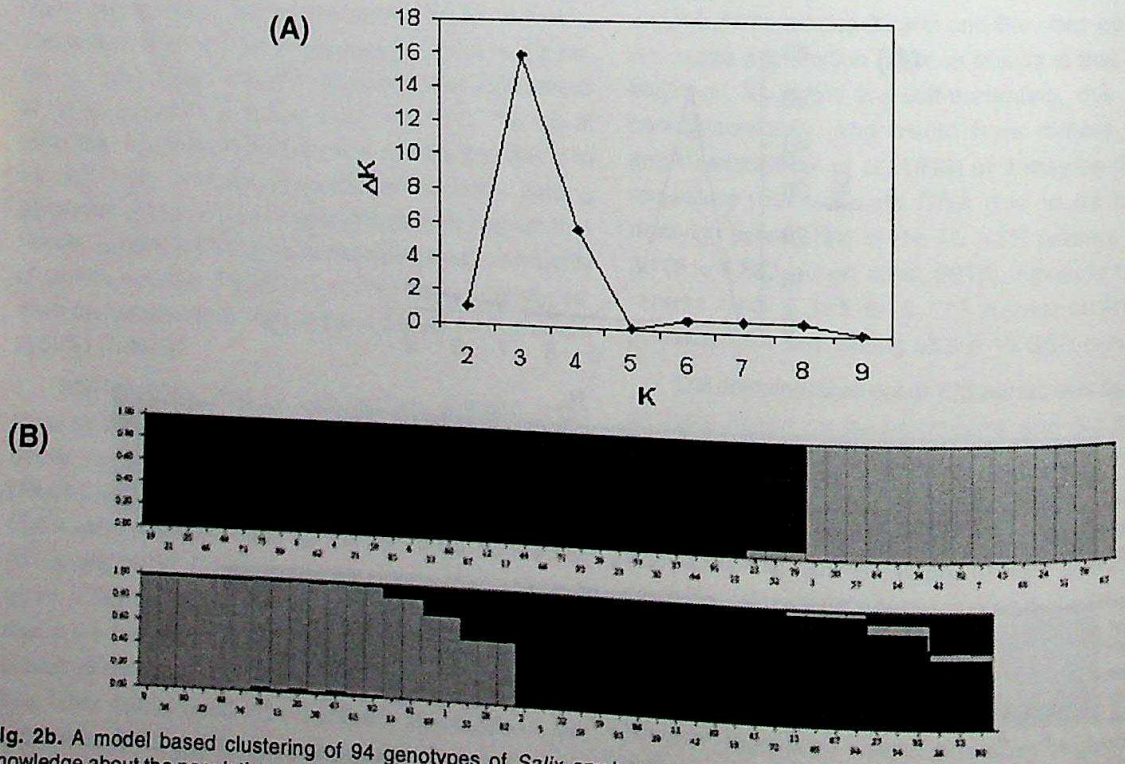

Fig. 2b. A model based clustering of 94 genotypes of *Salix sps* based on SSR profiling and using STRUCTURE without prior knowledge about the populations and under an admixed model. (A) The relationship between K and ΔK., i.e. ΔK is reaches its maximum when K = 3, suggesting that all genotypes fall into one of the 3 clusters. (B) Grouping of genotypes when K = 3. The genotypes were more likely clustered with respect to one of the 3 clusters. Genotypes from different clusters are represented with different colours.

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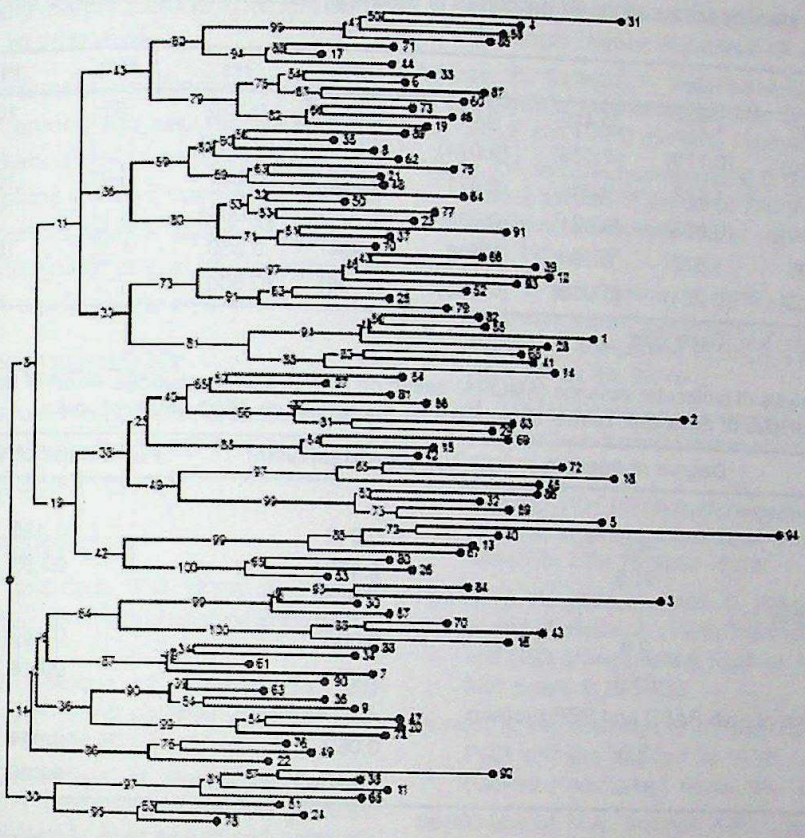

Figure 3a. Dendrogram generated by Neighbor joining (NJ) clustering technique showing relationships between 94 genotypes of *Salix* based on combination of both RAPD and SSR profiling. Number indicates bootstrap support values.

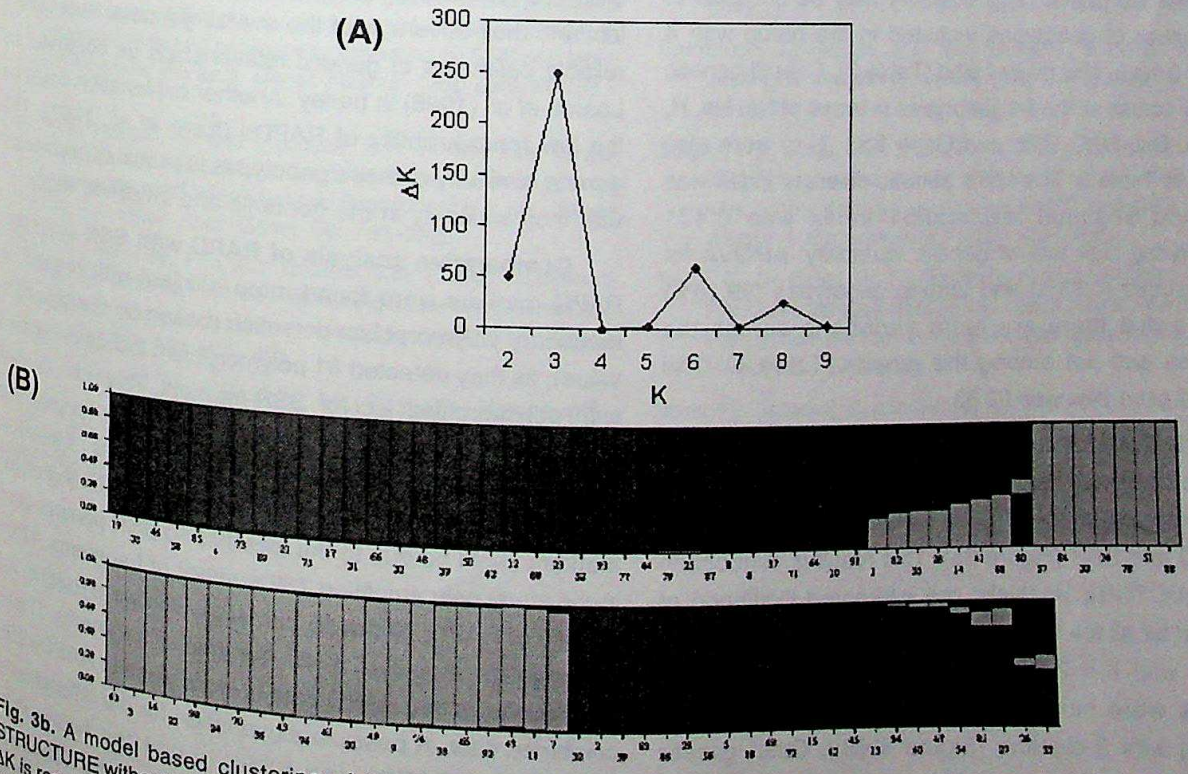

Fig. 3b. A model based clustering of 94 genotypes of *Salix sps* based on combination of RAPD and SSR profiling and using STRUCTURE without prior knowledge about the populations and under an admixed model. (A) The relationship between K and ΔK., i.e. ΔK is reaches its maximum when K = 3, suggesting that all genotypes fall into one of the 3 clusters. (B) Grouping of genotypes when K = 3. The genotypes were more likely clustered with respect to one of the 3 clusters. Genotypes from different clusters are represented with different colours.

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Table 3. Overall genetic variability across all the 94 genotypes of *Salix* spp. based on RAPD, SSR and combination of both RAPD and SSR markers

	Na	Ne	H	I	Ht	Hs	NPL	PPL	Gst	Nm
RAPD	2.00	1.721	0.412	0.601	0.412	0.410	61	100	0.042	70.93
	(0.00)	(0.179)	(0.065)	(0.071)	(0.004)	(0.004)				
SSR	2.00	1.422	0.296	0.471	0.296	0.291	59	100	0.025	32.83
	(0.00)	(0.063)	(0.031)	(0.038)	(0.001)	(0.001)				
RAPD+SSR	2.00	1.572	0.354	0.536	0.354	0.350	120	100	0.037	49.5
	(0.00)	(0.201)	(0.078)	(0.086)	(0.006)	(0.006)				

Gst, Genetic differentiation; Nm, Gene flow

Table 4. Summary of analysis of molecular variance (AMOVA) based on RAPD, SSR and combination of both RAPD and SSR markers among the genotypes of *Salix* spp. Levels of significance are based on 1000 iteration steps.

Source of variation	Degree of freedom	Variance component	Percentage of variation	P-value
(a) Based on RAPD profiling				
Among groups	2.0	0.042	0.496	-
Among genotypes	91.0	8.953	99.53	< 0.001
(b) Based on SSR profiling				
Among groups	2.0	0.063	0.880	-
Among genotypes	91.0	7.094	99.16	< 0.001
(c) Based on combination of both RAPD and SSR profiling				
Among groups	2.0	0.069	0.944	-
Among genotypes	91.0	7.242	99.06	< 0.001

diversity analysis in terms of Na, Ne, H, I, Ht, Hs, and PPL reveals higher value for the group with 4 female, 10 male, and 80 half sib plants. This disparity may be because of more number of genotypes included in the group with 4 female, 10 male, and 80 half sibs (Table 2). Overall genetic variability across all the 94 genotypes in terms of Na, Ne, H, I, Ht, Hs, Gst, NPL, PPL and Gene flow (Nm) were also included in Table 3. The Nei's genetic diversity index was 0.296 and Shannon information index was 0.471 demonstrating high rate of genetic variability. AMOVA for among groups (0.88%) and among genotypes (99.16%) indicated that there are more variations across the genotypes and not among the groups (Table 4). The estimated gene flow was 32.83.

RAPD and SSR combined data for cluster analysis: Based on combined data set of RAPD and SSR markers, the dendrogram obtained gave similar clustering pattern like RAPD and SSR (Figure 3a). This result is corroborate with STRUCTURE analysis; the estimated likelihood of distribution for all the 94 genotypes was highest i.e. ΔK was maximum with K = 3 (Figure 3b[A]), reveals that all the genotypes were clustered better (with high likelihood probability) with 3 clusters (Figure 3b[B]). Other genetic variation studies were also performed on RAPD and SSR combined data which are represented in different tables (Tables 3, 4 and 5). The differences found among the dendrograms generated by RAPDs and SSRs could be partially explained by the different number of PCR products analyzed reinforcing again the importance of the number of loci and their coverage of the overall genome, in obtaining reliable estimates of genetic relationships as observed by Loarce *et al.* (1996) in barley. Another explanation could be the low reproducibility of RAPDs (Karp *et al.*, 1997). The genetic similarity of these genotypes is probably associated with their similarity in the genomic and amplified region.

Comparative analysis of RAPD with SSR markers: RAPD markers were found more efficient with respect to number of polymorphism detection (based on average NPL value), as they detected 61 polymorphism loci as compared to 59 polymorphism loci for SSR markers. This is in contrast to the results obtained for several other plant species like wheat (Nagaoka and Ogihara, 1997) and *Vigna* (Ajibade *et al.*, 2000). More polymorphism in case of RAPD than SSR markers might be due to the fact that 10 SSR primers used in the study only amplified 732 number of fragments. While in case of RAPD, all the 15 primers which were used in the investigation amplified 1795 number of fragments (Table 1). This shows that RAPD data is more close to RAPD+SSR combined data. A possible explanation for the difference in resolution of RAPDs and SSRs is that the two-marker techniques target different portions of the genome. The mean effective multiplex ratio is more for RAPD (6.246) than that

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for SSR (4.588) and similarly marker index is more for RAPD (0.876) than that for SSR (0.751) markers.

Based on polymorphic feature, genetic diversity, genetic similarity, and gene flow among the populations of *Salix* based on molecular markers study, it is recommend that any future conservation plans for this species should be specifically designed to include representative populations with the highest genetic variation for both *in situ* conservation and germplasm collection expeditions.

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Genetic Resources of Bamboo in Orissa (India)

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Abstract: Orissa is traditionally an agrarian state and the rural people including tribals are very much dependent on bamboos since time immemorial. It holds over 134 million tonnes of bamboo, which exists mostly in the forest areas. The annual production of bamboo in the state is approximately 2 lakh tonnes of which 55,000 tonnes is produced from private land. *Dendrocalamus strictus, Bambusa bambos, Bamusa vulgaris* and *Bambusa nutans* are the major bamboo species of Orissa. *Schizostachyum pergracile, Gigamtochloa rostrta, Thyrsostachys oliveri* and *Bambusa tulda* are grown at small scale in specific locations either in forests or in village areas. Besides these more than fifty species of bamboo are grown in bambusetums of different organizations for conservation.

Key Words: Orissa, bamboo, genetic resource, conservation strategies

Orissa, the East Indian State, is unique in geography location, physiographical features, agro-ecological condition, demographic composition, natural resources and socio-cultural heritage. It holds both coastal and continental climate. It has 155707 km² geographical area, which constitutes 4.74% area of the country. The state lies between latitude 17°47' and 22°34' N and longitude 81°22' and 87°29' E and experiences both tropical and sub-tropical climate. Physiographically, the state can be divided into four regions, viz. Northern Plateau, Eastern Ghats, Central Tableland and Coastal Plains. It has been divided into 10 agro-climatic zones based on land farm, topography, climate, soil and coastal plains. The average annual rainfall varies from 1200 to 1600 mm and mean annual temperature ranges between 25 to 27.5°C. The state is rich in groundwater, mineral wealth, fertile soil and diverse flora and fauna. The state has more than 480 km coastal line. As per the census 2011, the total population of the state is 41947358. The rural population constitutes 85% of the total population. The scheduled tribe and scheduled caste population constitute 22 % and 16.5% of the population, respectively. The above facts have led the state traditionally an agrarian state and the rural population including tribals have been depending on forests including bamboos since time immemorial.

The state has forest area of 48,855 km², which is 31.38% of the state's geographical area (FSI, 2009). The state has 19 different forest types as per Champion and Seth's classification 1968 belonging to 4 type groups viz. Northern Tropical Semi Evergreen, Northern Tropical Moist Deciduous, Littoral and Swamp and Northern Tropical Dry Deciduous Forests. The major species occupying the Orissa forests are sal, teak and bamboo. The approximate area under forests of different major species are : sal forest – 16938. 25 km², miscellaneous forest – 21024.34 km², teak forest – 2030.64 km², pure bamboo forest – 474.77 km², mixed bamboo forest – 17794.61 km² and mangrove forest – 219 km². The agro-ecological and socio-cultural features of Orissa have led bamboo to be associated closely with people of Orissa. This state has potential to accommodate a vast genetic resources of bamboo. An attempt has been made to compile and document information on genetic resources of bamboo in Orissa, which will be useful to common people, researchers, students, foresters, bamboo entrepreneurs and other stake holders of bamboo.

Bamboo Resource in Orissa

Orissa posses the third largest bamboo resource of India after Madhya Pradesh and Maharashtra containing 8.7% of the bamboo area. It accounts 7% of the estimated stock of the country bearing over 134 million tonnes, which exists mostly in the forest areas. In Orissa, bamboo is grown in forest areas as well as non-forest areas. In forest areas *Dendrocalamus strictus* (salia bamboo) and *Bambusa bambos* (daba bamboo) area the dominating bamboo species, whereas, in homesteads and cultivated areas *Bambusa vulgaris* (sunderkani bamboo) and *Bambusa nutans* (badia bamboo) are the dominating bamboo species. All the 30 districts of Orissa have bamboo resources. Concentration of bamboo is high in Mayurbhanj, Keonjhar, Sambalpur, Nayagarh in North Orissa, Kandhamal (Phulbani), Kalahandi, Ganjam, Koraput in South and South-Central Orissa. The annual production of bamboo in the state is approximately 2 lakh tonnes of which 55,000 tonnes is produced from private land.

I. Major Bamboo Species in Orissa

There are four major bamboo species grown in Orissa such as *Dendrocalamus strictus, Bambusa bambos, Bamusa vulgaris* and *Bambusa nutans* (Swain, 2005). The former

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two species generally occur naturally in forest areas and later two are cultivated in private lands. The farmer two species are also found outside forest areas in small extent and even grown by people in private lands. The specific characteristic, distribution and uses of these species in Orissa are given here.

A) *Dendrocalamus strictus* Roxb.: This is the most gregarious natural bamboo of Orissa and locally called as salia baunsa. Generally, it is a deciduous and densely clumped species. There are three different variants of this bamboo such as (i) tall culms with moderately thick walls and a small lumen generally found in moist hill slopes of Ganjam and Phulbani districts, (ii) culms of medium height, fully solid or nearly so and 3-4 cm in diameter and (iii) culms with larger lumen and thin walls generally found in depressions and dry areas. Salia bamboo is used for construction of houses, agricultural implements, musical instruments, furniture, mats, baskets and above all paper and pulp. Young shoots are commonly used as food.

B) *Bambusa bambos* Voss. : This is a large thorny bamboo species forming dense clump. Two variants of this are found in Orissa, one being very tall with large diameter and lumen (locally called as Daba baunsa) and the other producing medium sized but think walled culms (locally called as Kanta baunsa). The former is seen in moist valleys in semi-evergreen forests and the latter in the lateritic soil. The most common use of this species is for paper and pulp. It is used for rafters, scaffolding, roof thatching, cart making, basket making, furniture making, etc. The thorny branches are used for fencing. Young shoots are edible. Wild animals particularly elephants and gaur relish the young shoots in forests.

C) *Bambusa vulgaris* Schrad.: This is the commonly cultivated and moderate sized bamboo in Orissa and locally called as Sunderkani baunsa. The cultivation package of this species has been developed at Orissa University of Agriculture and Technology, Bhubaneswar (Bhol and Nayak, 2008). There are three variants of this species found in farmlands of Orissa, (i) one has very tall culms with bigger diameter, much hollow inside and arching above 2/3rd of its height, (ii) second is of medium height, thick walled, comparatively erect and arching towards top and (iii) third variant has culms of 6-8 m high, 4-5 cm diameter and very much arching from the mid height. This species flowers sporadically in very few culms in the state, but does not produce seeds (Bhol, 2006; Bhol and Nayak, 2010).This species is extensively used for construction, implements, manufacturing of household articles and handicrafts. The artisans prefer this bamboo as compared to salia bamboo.

D) *Bambusa nutans* Wall.: This is a big sized, luxuriant, cultivated bamboo and locally called as badia baunsa. This species flowers sporadically in very few culms in Orissa. The flowering occurs either in parts of the clump or in whole clump. This is commonly cultivated in the villages particularly in Mayurbhanj and Baleshwar districts of the state, occasionally planted in other districts. This is the most preferred bamboo species in the state for building purposes and for scaffolding. The culm is good, strong and straight, thus has a variety of uses. It is also used for mat making and incense sticks. Large quantities of culms are supplied to paper pulp industries and bamboo wood chip industries.

II. Bamboo Species Grown on Limited Scale

There are four bamboo species such as *Schizostachyum pergracile, Gigamtochloa rostrta, Thyrsostachys oliveri* and *Bambusa tulda* are grown on small scale in specific locations either in forests or in village areas. The specific characteristics, distribution and uses of such species in Orissa are given here.

A) *Bambusa tulda* Roxb.: It is locally called as tarala or taleda baunsa. It is a densely tufted bamboo forming dense clump. This species is cultivated in different parts of the state in limited scale, but found relatively more in Baleshwar and Mayurbhanj districts. It is preferred in basket making and woven applications. It is very often used in cultivation of betel vine and roof of thatched houses. It is suitable for mechanized processing for bamboo boards and composites and for manufacture of wrapping, writing and printing paper. Young shoots are used for making excellent pickles.

B) *Schizostachyum pergracile* Munro: Its synonym is *Cephalostachyum pesgracile* Munro and locally it is called as dangi baunsa. It is a deciduous, arborescent, tufted bamboo of moderate size. This species is found occasionally in shady valleys and near streams/nalla banks deep inside the forests. The clumps are found on the lower slopes of hills where *Dendrocalamus strictus* is found on higher slopes. The sporadic clumps are found in Dango-West reserve forest of Phulbani Forest Division. The bamboo is soft and the green culm has the property to split and crack on drying. Because of softness even at the nodes, it is extremely popular among the artisans for making fine works such as hats, flower baskets, decorative mats, etc. The single internode culm pieces are used as blow pipes by rural women for fanning fire in the hearth.

C) *Gigantochloa rostrata* Wong.: Its synonyms are *Gigantochloa maxima* var. *minor* Holttum and *Oxytenanthera nigrociliata* Munro. It is locally called as bolangi or pani

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baunsa. It is a tufted dark green bamboo of small size and forms dense clump. This species is found in moist valleys along the stream banks in Khurda and Kandhamal district. The bamboo is used for making huts and baskets. Its special use is for stitching leaf plates. It is said that tribal women present bundles of stitching sticks prepared from this bamboo to their relatives as gift while they visit them where this is not available.

D) *Thyrsostachys olivari* Gamble : This is called as nala baunsa locally. It is a moderate sized tufted elegant bamboo. This species is a native of Myanmar (Burma). It is believed that it has been brought from Burma and introduced by some people of Nayagarh and Ganjam district of the state who were working there long years ago. This bamboo is used for construction of thatch houses, basket making and mat making. Farmers prefer it to use as pole or stick required in agricultural works. This species has potential to be included in agroforestry systems because of small crown and straight growing behaviour.

III. Bamboo Species Grown Sparsely

There are some bamboo species grown by people in countable number of clumps primarily for ornamental purpose. However, these can be used for construction works. These are grown in parks, gardens and/or homesteads. This category includes the species given in Table 1.

IV. Bamboo Species Grown in Bambusetums/ Germplasm Banks

In Orissa different organizations like State Forest Department, Orissa University of Agriculture & Technology, Regional Plant Resource Centre, etc. are engaged in research and development of bamboo. These organizations are maintaining few clumps of different bamboo species in their respective bambusetums/germplasm banks (Table 2).

Besides these species, the common bamboo species like *Dendrocalamus strictus, Bambusa bambos* and *Bambusa vulgaris* are grown in small blocks in other silvicultural gardens of the state.

Recent Initiatives to Enhance Bamboo Resources

The Government of Orissa has set up Orissa Bamboo Development Agency (OBDA) during the year 2007 for addressing all aspects of bamboo sector development including enhancing the bamboo resources of the state. Under this, a state plan scheme called Orissa Bamboo Development Programme has been launched since 2008-2009 and over 2574 hectares of bamboo plantations have been established by 2011-2012 (OBDA, 2011). Bamboo plantation is even being encouraged under MGNREG scheme. To encourage easy removal of bamboo from private lands vis-à-vis more bamboo plantation, the species mostly grown and found on such lands viz. *Bambusa vulgaris, Bambusa nutans* and *Bambusa tulda* have been exempted from the purview of transit permit.

National Bamboo Mission (NBM) is also operating in Orissa since 2006. So far 3902 hectares of plantations have been taken up in forest areas over 36 Forest Divisions with major concentration in Bolangir, Ghumsur, Kalahandi, Koraput and Baripada Divisions. Similarly in non-forest areas, 2225 hectares covering 2885 beneficiaries in 25 districts with major concentration in Baleshwar, Mayurbhanj, Kalahandi, Ganjam, Koraput and Kandhamal districts have been developed (OBDA, 2011).

Orissa is a potential state to accommodate vast genetic resources of bamboo and utilize them for wellbeing of people. The rural population which accounts about 85% of the total population is very much dependent on bamboo besides there is wide use of bamboo in urban areas and

Table 1. Particulars of bamboo species grown in few individuals in Orissa (India)

S. No.	Species	Local name (Oriya name)	Brief characteristics in Orissa condition
1.	*Bambusa striata* Lodd. ex Lindl. / *B. vulgaris* var. *striata* Lodd. ex. Londl.	Champa baunsa	A graceful tufted bamboo. Culms 8-10m high, 4-7cm diameter, yellow with light green stripes or rarely light green with yellow stripes. Internodes 15-25cm long, thick walled.
2.	*Bambusa wamin* Camus / *B. vulgaris* cv. *wamin* McClure	Budhapeta baunsa/ Bottle baunsa	A medium to small size graceful bamboo, culms 3-6m high, loosely tufted usually arching at top, dark green, shinning, glabrous. Internodes 10-15cm long much swollen (pitcher shaped) in the lower half, lower 3 or 4 nodes with root lets.
3.	*Thyrsostachys regia* (Munro) Bennet/ *Thyrsostachys siamensis* Gamble	Lathi baunsa	A grraceful small bamboo. Clump is compact with culms, which curve out at upper height. Culms 5-7m high, 2-4cm diameter, thick walled, usually covered with persistent sheaths, nodes hardly thickened with a white band below. Internodes 25-30cm long, light green.
4.	*Dendrocalamus giganteus* Munro/ *Bambusa gigantea* Wall.	Rakshasha baunsa	It is the longest bamboo with close culms and slender branches. Culms 20-25m tall, 15-25cm diameter, usually 1.5-2.0cm thick walled, dull green covered with white waxy crust when young. Internodes 35-40cm long, lower nodes with root scars.

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Table 2. List of bamboo species grown in bambusetums/germplasm banks of different organizations of Orissa (India)

A. Bamboo species at Bambusetum (inside Knowledge Centre of Orissa Forest Department), Bhubaneswar

S. No.	Species	S. No.	Species
1.	*Bambusa glaucascence*	32.	*Dendrocalamus hookeri*
2.	*Bambusa aureostriata*	33.	*Dendrocalamus sikkimensis*
3.	*Bambusa affinis*	34.	*Dendrocalamus stocksii*
4.	*Bambusa assamica*	35.	*Dendrocalamus strictus*
5.	*Bambusa arundinacea*	36.	*Dinochloa compactiflora*
6.	*Bambusa balcooa*	37.	*Gigantochloa albociliata*
7.	*Bambusa burmanica*	38.	*Gigantochloa atroviolacea*
8.	*Bambusa cacharensis*	39.	*Gigantochloa manggong*
9.	*Bambusa giganteus*	40.	*Guadua angustifolia*
10.	*Bambusa goruchakua*	41.	*Melocalamus maclellandi*
11.	*Bambusa longispiculata*	42.	*Melocanna baccifera*
12.	*Bambusa membranaceus*	43.	*Ochlandra ebrecteata*
13.	*Bambusa nangal*	44.	*Ochlandra scriptoria*
14.	*Bambusa nutans*	45.	*Ochlandra travancorica*
15.	*Bambusa pallida*	46.	*Oxytenanthera parvifolia*
16.	*Bambusa polymorpha*	47.	*Oxytenanthera abyssinica*
17.	*Bambusa striata*	48.	*Oxytenanthera nigrociliata (Giantochloa rostrata)*
18.	*Bambusa tapi*	49.	*Oxytenanthera stocksii*
19.	*Bambusa tulda*	50.	*Phyllostachys aurea*
20.	*Bambusa ventricosa*	51.	*Phyllostachys mannii(assamica)*
21.	*Bambusa vulgaris*	52.	*Phyllostachys nigra*
22.	*Bambusa wamini*	53.	*Phyllostachys bambusoides*
23.	*Cephalostachyum pergracile*	54.	*Pseudossasa japonica*
24.	*Dendrocalamus giganteus*	55.	*Pseudoxytenanthera ritcheyi*
25.	*Dendrocalamus hamiltonii*	56.	*Sasa fortunei*
26.	*Dendrocalamus longispathus*	57.	*Schizostachyum dullooa*
27.	*Dendrocalamus membranaceus*	58.	*Schizostachyum glaucifolium*
28.	*Dendrocalamus multiplex*	59.	*Schizostachyum japonica*
29.	*Dendrocalamus asper*	60.	*Schizostachyum polymorphum*
30.	*Dendrocalamus brandisii*	61.	*Thyrsostachys oliveri*
31.	*Dendrocalamus calostachys*	62.	*Thyrsostachys regia*

B. Bamboo species at Kalinga Research Garden (Silviculture Division, Orissa Forest Department), Kalinga

S. No.	Species	S. No.	Species
1.	Bambusa nutans	10.	*Dendrocalamus calostachyus*
2.	Thyrsostachys oliveri	11.	*Bambusa balcooa*
3.	Dendrocalamus strictus	12.	*Bambusa striata*
4.	Bambusa wamin	13.	*Bambusa tulda*
5.	Bambusa vulgaris	14.	*Thyrsostachys regia*
6.	Bambusa bambos	15.	*Bambusa polymorpha*
7.	Dendrocalmus giganteus	16.	*Gigantochloa rostrata*
8.	Dendrocalamus membranaceus	17.	*Melocana baccifera*
9.	Dendrocalamus hamiltonii	18.	*Dendrocalamus asper*

C. Bamboo species at Khandagiri Research Garden (Silviculture Division, Orissa Forest Department), Bhubaneswar

S. No.	Species	S. No.	Species
1.	Bambusa bambos	6.	*Dendrocalamus strictus*
2.	Bambusa vulgaris	7.	*Dendrocalamus giganteus*
3.	Bambusa nutans	8.	*Thyrsostachys oliveri*
4.	Bambusa tulda	9.	*Thyrsostachys regia*
5.	Bambusa striata	10.	*Bambusa wamin*

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D. Bamboo species at College of Forestry, Orissa University of Agriculture and Technology, Bhubaneswar

S. No.	Species	S. No.	Species
1.	*Bambusa vulgaris*	6.	*Bambusa balcooa*
2.	*Bambusa bambos*	7.	*Thyrsostachys oliveri*
3.	*Dendrocalamus strictus*	8.	*Dendrocalamus brandisii*
4.	*Bambusa striata*	9.	*Bambusa wamin*
5.	*Bambusa nutans*	10.	*Ochlandra travancorica*

E. Bamboo species at Regional Plant Resource Centre, Bhubaneswar (RPRC,2009)

S. No.	Species	S. No.	Species
1.	*Bambusa arundinacea*	16.	*Dendrocalamus strictus*
2.	*Bambusa balcooa*	17.	*Dinochloa maclellandii*
3.	*Bambusa multiplex*	18.	*Gigantochloa rostrata*
4.	*Bambusa nutans*	19.	*Melocana baccifera*
5.	*Bambusa polymorpha*	20.	*Oxytenanthera nigrociliata*
6.	*Bambusa ventricosa*	21.	*Phyllostachys aurea*
7.	*Bambusa vulgaris*	22.	*Phyllostachys nigra*
8.	*Bambusa vulgaris "Vittata"*	23.	*Pleioblastus fortunei*
9.	*Bambusa tulda*	24.	*Pleioblastus pygmaeus*
10.	*Bambusa wamin*	25.	*Pseudossasa japonica*
11.	*Bambusa nangal*	26.	*Sinarundinaria longispiculata*
12.	*Bambusa tapi*	27.	*Thyrsostachys oliveri*
13.	*Dendrocalamus giganteus*	28.	*Thyrsostachys regia*
14.	*Dendrocalamus hamiltonii*	29.	*Thysanolaena maxima*
15.	*Dendrocalamus membranaceus*		

paper mills. Although 12 species of bamboo have naturalized in the state, another 50 plus species are growing in different bambusetums. The state has potential to explore the genetic resources of bamboo for development of bamboo sector in the state.

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Indian Journal of Ecology

Agroforestry: An Approach for Food Security

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Abstract: Periodic unavailability of farm inputs, degradation of natural resources and population explosion problems are the main causes of food insecurity. Intensive agricultural practices required to meet food requirements of increasing human population, led to large scale resource degradation. The unavailability of natural resources, high costs and periodic limited availability of mineral fertilizers and other farm inputs have reduced the farm production. The past approaches in agriculture production have failed to reduce food insecurity and sustainability in production. Agroforestry science, and its application by smallholders throughout the tropics, have a potential and played an important role in achieving sustainability in farm productivity. The incorporation of a diverse variety of trees into agricultural systems can increase crop productivity and incomes of smallholding farmers through diverse products *viz.*, edible flowers, fruits and fodder. The well managed multipurpose tree species on farm benefits in the case of efficient use of natural resources enhance the overall (biomass) productivity, improvement in soil fertility, soil conservation and nutrient cycling, micro-climate amelioration, carbon sequestration, bio-drainage, bio-energy and bio-fuel production etc. Nowadays farmers, researchers, policy makers are interested in agroforestry for its ability to contribute in meeting deficit of agricultural and tree products with socio-economic and environmental benefits.

Key Words: Farm productivity, sustainability, agroforestry, livelihood security

Rising human population, abrupt climate changes and unsustainable utilization of natural resources, are the main reasons of decreasing farm productivity. Generally assume that food production is the base for food security but it is not so and food security will not be achieved by focusing only on the increasing crop productivity. However, some researcher suggests that the food scarcity is primarily caused by inadequate distribution, a lack of purchasing power and other non-productive causes. Thus, the emphasis on food production alone is not sufficient to insure future food security but involves judicious use of natural resources, changing climate, socio-economics, etc. FAO has defined food security as a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Agroforestry is a wide-spread land-use system. Agricultural crops, vegetables, forest and horticultural trees, shrubs and grasses are the system components, which made it diverse and productive. It may potentially support livelihoods improvement through simultaneous production of food, fodder and firewood as well as mitigate the problems created by abrupt climate change. Through increasing diverse food production, resource conservation, employment generation and enhancing rural income, agroforestry systems may solve food insecurity problems (Pandey, 2007; Singh and Pandey, 2011; Sharma *et al.*, 2007). Current area under agroforestry is 7.45 million ha, has potential to extend up to 25.36 million ha by next two decades and will meet increasing food requirements of the country (Dhyani *et al.*, 2009).

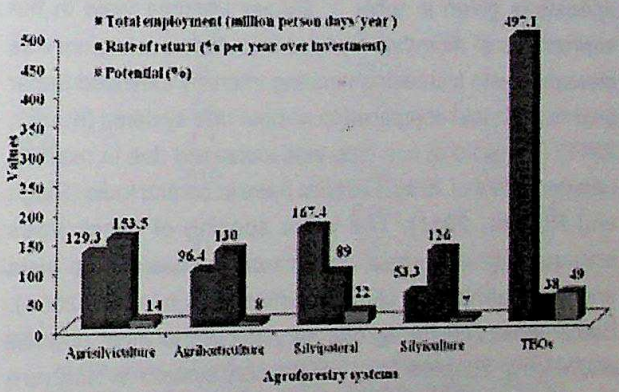

Fig.1. Agroforestry adoption, rate of return and total employment potential (Dhyani *et al.*, 2009)

Resource Conservation and Efficient Utilization

Water and soil nutrients are the most important resources for farm productivity. Continuous resource depletion decreases productivity of the farmlands. Intensive agriculture, climate change and unsustainable use of resources are the main causes of resource degradation. Trees in agro-ecosystems can enhance soil productivity through conservation and efficient use of natural resources (Kumar, 2011). Cardamom based agroforestry system from the North-East India reported best agroforestry system for resource conservation (Sharma *et al.*, 2007). The runoff and soil erosion losses were arrested through *Leucaena* based

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alley cropping system and improve average soil moisture (Burman and Gill, 2001). *Prosopis cineraria* and *Tecomella undulata* maintained at optimum tree densities can enhance productivity of associated agricultural crops by improving soil water, organic matter and N availability in degraded lands of Indian desert (Singh, 2009). The coconut-based poly-cultural systems often include diverse kinds of woody perennials, ensures more efficient resource utilization (Kumar, 2006 and 2011). Combining grasses and legumes, such as *Stylosanthes guyanensis*, *Panicum maximum*, *Setaria*, etc. with fodder trees, such as alder (*Alnus nepalensis*) in a silvi-pastoral system stabilizes terrace risers and increases water use efficiency (Fanish and Priya, 2013).

Increase Food Production

The diverse food productions through agroforestry systems are widely contributing to solve food insecurity problems. Applications of agroforestry practices on wasteland are defiantly going to increase country's food production potential. The fig.1 showes the potential of most widely adopted agroforestry systems of India. Woody perennial components may cause competition with annual crops; however, it showed food production potential on degraded lands with appropriate management practices. The yield of some important food crops under different woody species is given in table 1. Ginger rhizome yield in the interspaces of *Ailanthus triphysa* and *Acacia mangium* was increased with increasing thinning intensity exhibited better growth and yield compared to without tree systems (Kumar, 2011). The yield of rice crop was increased due to residual nitrogen effect of *Acacia nilotica* trees in central India (Singh and Pandey, 2011). The wider spacing of kapok trees intercropping with wheat significantly increases crop yield and yield attributing characteristics (Singh *et al.*, 2004). Poplar-wheat based agroforestry system is most popular and widely adopted food production system in northern plains of India (Chauhan *et al.*, 2010).

Increase Livestock Production

Silvi-pastoral system from different regions (arid, semi-arid and hill) of India widely provides fodder for grazing animals during lean period. Nutritive fodder from *Albizia amara*, *Leucaena leucocephala* trees and *Chrysopogon fulvus*, *Sehima* spp., *Heteropogon* spp. grasses, *Stylosanthes hamata*, *S. scabra* pasture legume species increases body weight of goat and sheep. *Prosopis cineraria*, *Grewia optiva*, *Celtis australis* and *Morus alba* other fodder yielding tree species has potential to provide fodder in fodder deficient period. Forage yield of 13.5 t/ha was obtained from the combination of *Stylosanthes* and *Setaria* from silvi-pastoral system, which improves livestock production (Fanish and Priya, 2013).

Nutrition and Health

Advances in agroforestry have many links with improving the health and nutrition of the rural poor people. Fruit plants are the most valuable component of agri-horticulture systems. The fruit tree cultivation on farms can have a significant effect on the quality of child nutrition. This is particularly important as indigenous fruit tree resources in local forests are overexploited. They yield nutritious fruits and serve rich source of minerals, vitamins and important alkaloids. The nutritional status of important fruit crops is given in table 2. Local peoples are widely using these fruits in their diets and medicine as well.

Increase Wood and Non-wood Forest Products

More than half of the timber requirement is being met from agroforestry systems. *Eucalyptus*, poplar, *Salix*, *Acacia mangium* and *Casuarina* are the most important industrial agroforestry tree species. The 50 % of the demand of fuel wood is being met from farmlands and community land (Dhyani *et al.*, 2009). Home gardens in the state Kerala with a diverse tree and shrub species constitute a principal source of bio-fuels for most (51% to 90%) rural households (Kumar, 2011).

Enhance Rural Income

The TBOs (Tree born oil seeds) based system generates employment to the 497.1 million persons per year, whereas, agri-silviculture gives 153.5% rate of return (Fig. 1). The intensity of profit generation was highest for the smaller home gardens with both adaptive managements and the presence of other intangible benefits. Enhancing rural income through agroforestry systems helps to poverty alleviation (Garrity, 2004). The net present value for the different agroforestry models on six years rotation in Haryana varied from Rs. 26626 to Rs.72705 ha^{-1} yr^{-1}, whereas, the benefit:cost ratio and the internal rate of return varied from 2.35 to 3.73 and 94 to 389%, respectively (Kumar *et al.*, 2004). Average net monetary benefit from guava based agroforestry systems was Rs. 20,610 per hectare and Rs. 13,787.60 per hectare from lemon based agroforestry systems in Assam. Such systems are most useful livelihood improvement strategies in the rainfed systems (Bhatt and Misra, 2003). The combination of *Acacia* and rice traditional agroforestry system has a benefit/cost (B/C) ratio of 1.47 and an internal rate of return (IRR) of 33% at 12% annual discount rate during a ten year period (Viswanath *et al.*, 2000). In case of commercial agroforestry systems, additional

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Table 1. Productivity of food crops under different agroforestry systems

Agroforestry systems Plant species	Agri-silviculture	Horti-silviculture	Agri-horticulture	Home gardens/ Plantation crop based systems	Sources
Triticum aestivum L.	25.60 q ha^{-1}				Singh *et al.* (2004)
Oryza sativa L.	37.07 q ha^{-1}		30.58 q ha^{-1}		Thaware *et al.* (2004); Tomar and Bhatt (2004)
Sorghum bicolor L. Moench	16.90 q ha^{-1}				Divya *et al.* (2004)
Vigna radiate L.	8.64 q ha^{-1}				Pandey and Tewari (2004)
Glycine max L. Merril	14.2 q ha^{-1}				Mishra *et al.* (2004); Patil *et al.* (2012)
Brassica campestris L.			5.77 q ha^{-1}		Lal *et al.* (2004)
Brassica juncea L.	10.62 q ha^{-1}				Lal *et al.* (2004)
Solanum tuberosum L.		131.1 q ha^{-1}			Kumar and Nandal (2004)
Citrus limon (L.) Burm.F.			27.61 q ha^{-1}		Tomar and Bhatt (2004)
Prunus persica (L.) Stokes			64.44 q ha^{-1}		Tomar and Bhatt (2004)
Psidium guajava L.			58.11 q ha^{-1}		Tomar and Bhatt (2004)
Zizyphus mauritiana			140.55 q ha^{-1}		Zhang *et al.* (2013)
Zingiber officinale Roscoe			127.07 q ha^{-1}		Vanlalhluna and Sahoo (2009)
Curcuma longa L.				115.22 q ha^{-1}	Vanlalhluna and Sahoo (2009)
Theobroma cacao L.				37.28 kg tree^{-1}	Isaac *et al.* (2007)

Table 2. Nutritional value of fruit plants used in agroforestry systems

Nutritional value	Aonla	Ber	Jamun	Mahua	Imli	Bael
Carbohydrates (%)	14	17.1	19.7	22.9	67.4	31.8
Protein (%)	0.5	0.8	0.7	1.4	3.1	1.8
Fat (%)	0.1	0.3	0.1	1.6	0.1	0.4
Ca (mg/100g)	50	4.0	20	45	170	-
P(mg/100g)	20	9.0	10	22	110	-
Fe(mg/100g)	1200	1.8	1000	1.1	11	-
Vit-A(mg/100g)	-	0.002	-	512	0.06	55
Vit-B(mg/100g)	30	0.74	-	-	0.14	1.32
Vit-C(mg/100g)	600	76	-	41	3.0	8.0

income (71.3 %) was the major factor in their adoption (Dwivedi *et al.*, 2007).

Agroforestry has potential to increase food production through resource conservation, reclamation of degraded lands and efficient use of natural resources. The diverse and nutritious food production will be the major component of the food security policy statement. It also helps to ensure livelihood security through generating rural income and employment.

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Nursery Evaluation of Selected Tree Willow (*Salix* Spp.) Clones: Estimation of Variability, Heritability, Genetic Gain and Correlation

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Abstract: The promising *Salix* species/clones and hybrids were procured from different countries and introduced at UHF Nauni, Solan, India during the year 2002-04. After nursery screening, the selected clones were planted in the field. These selected clones were repeatedly raised in nursery every year from 2011 to 2013 to find out the most adaptive and superior clones along with check clone (Kashmiri willow). Plant survival, height and basal diameter were recorded and volume index was calculated. The data revealed significant differences among clones. Plant survival was at par among clones except in clones J194, NZ1002 and V-311. Maximum plant height (389.77 cm) was recorded by clone J799 followed by clones J795 (355.36 cm) and NZ 1002 (344.95 cm). Basal diameter was recorded at par in the clones SI-64-017 (17.66 mm), J799 (17.52 mm), NZ1002 (16.49 mm), 131/25 (16.25 mm) and NZ1140 (16.11 mm). The clone J799 recorded maximum (1329 cm^3) volume index, which was at par with clone SI-64-017 (1171 cm^3) followed by clone NZ 1002 (1015 cm^3). Check clone Kashmiri willow remained at 5th, 6th, and 7th position for basal diameter, plant height and volume index, respectively. The selected clones have to be tested in the field conditions to find the genotype x environment interaction.

Key Words: Willow, clones, genotype x environment interaction, heritability, genetic gain, correlation, volume index

The genus *Salix* is popularly known for its fast growth, wide geographic adaptation with a significant economic value. It comprises of about 350–500 species worldwide (Argus, 1997), distributed over wide ecological and climatic zones ranging from North America to China, excluding Australasia (Trybush *et al.,* 2008). These are multipurpose and eco-friendly species having variety of end uses viz., baskets, cricket bats, hurdles, furniture, plywood, paper and pulp, rope making, etc. (Verwijst, 2001; Kuzovkina *et al.,* 2008; Andleeb *et al.,* 2011; Sharma *et al.,* 2011). The arborescent willow species are able to grow on various types of soil and are most suitable for the biological control of soil erosion, siltation, nutrient recycling, phyto-remediation, carbon sequestration and filtering of sewage polluted water (Zalesny and Bauer, 2007).

In India, there are about 31 indigenous and 4 exotic species of willows (Saini and Sharma, 2001) but majority of them are not suitable for industrial use (Sharma *et al.,* 2011 and Singh *et al.,* 2012a). Under short rotation forestry, they are better adopted in monoculture as well as in agroforestry system. Sinha and Sharma (2002) have emphasized the suitability and growth pattern of *Salix* species in Himalayan foot hills. Most of the arborescent species of *Salix* are confined to hilly region of the country except *S. tetrasperma* and *S. babylonica,* which occur right from tropical to temperate regions of India (Sharma *et al.,* 2011).

Stability of clones for growth and yield traits helps in enriching the tree improvement programme by assessing the profitability of a plantation because grower can choose the most stable material to the specific site (Sixto *et al.,* 2011). Stability analysis is done from the data of replicated trials conducted over many locations or for many years on same location or both (Gupta *et al.,* 1997). Different environmental conditions created at one location are a common practice in agriculture crops to find the stable genotypes for various climates (Sharma, 2006). Keeping in view the ever increasing demand of willow wood for multifarious uses particularly for sports good manufacturing entrepreneurs, household timber, constituted wood, etc., selected promising clones from by various research organizations through out the world (Table 1), were procured and introduced at university of Horticulture and Forestry campus, Solan (HP) followed nursery screening for three years (Singh *et al.,* 2012). A field trial of 20 superior clones was raised in the experimental area in each year from 2011 to 2013 to identify stable clones for variable environmental conditions. Considering different years as a different location, stability of clones can be worked out (Sharma, 2006) to identify clones stable for variable environmental conditions.

MATERIALS AND METHODS

The experiment was carried at Naganji nursery area of the Department of Tree Improvement and Genetic Resources, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The nursery site is located at an elevation of 1200 m above mean sea level in the north-west of Himalaya and lies between 30°51'N latitude and

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76°11'E longitude having well drained, sandy loam soil with pH of 7.20. The area experienced a wide range of temperature (Fig. 1a) with a minimum of 0.4°C in winters to a maximum of 32.3°C during summer. The annual rainfall ranges (Fig. 1b) between 298.3-1024.3 mm with maximum downpour during the monsoon season (July-September). The 20 clones were raised in three replications in Randomized Block Design with 16 ramets in each replication. Stem cuttings of 22.50 cm long and 1 cm thick were prepared from one year old nursery plants.

The spacing between rows was 50 cm and between cuttings in a row was 40 cm in a sunken bed of size 250 cm x 150 cm under the usual nursery conditions. Singling of stem was done. The plants were regularly watered and weeding and hoeing in beds were done whenever necessary.

The observations were recorded in the month of December when the saplings were nine months old. Plant height in centimeter and basal diameter in milimeter was measured. Volume index was calculated by multiplying plant height with square of basal diameter. The data was statistically analyzed with the statistical package for social sciences (SPSS), version 16.0.

Genotypic, phenotypic, environmental variances and coefficients of variability, expected genetic advance at 5 per cent of selection intensity was calculated by the formula given by Singh (2006). Genetic gain was worked out following the method suggested by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Plant survival and growth: Data revealed that clones and year varied significantly for all the traits (Table 1 and 2). The clone x year interaction was found non-significant except for plant survival. Growth of plants was recorded highest in the year 2013 (plant height, 337.78cm; basal diameter, 16.45mm and volume index, 1023 cm^3). Mean plant height, basal diameter and volume index of 309.28cm, 14.91mm and 775.37 cm^3, respectively was recorded for all the clones.

Data in table 2 revealed that clone J799 recorded maximum plant height in the year 2011 (347 cm) and 2013 (425.76cm), while it was recorded by clone J795 in the year 2012 (398.27cm). Plant height was recorded at par with clone J799, clones SE-63-016 (309 cm) and PN 731 (301 cm) in the year 2011, clone NZ 1002 (388.49 cm) in the year 2013 and clones J799 (396.88 cm) and 131/25 (360.94 cm) with clone J795 in the year 2012. Mean plant height was recorded maximum (389.77cm) in the clone J799 followed by clones J-795 (355.36 cm) and NZ 1002 (344.95 cm).

Basal diameter was recorded maximum in the clone SI-64-017 in the year 2011 (17.69 mm) and 2012 (16.28 mm) while in the year 2013, it was recorded by clone J799 (19.88mm). In the year 2011 clone J799 (17.47 cm) and in the year 2013 clones NZ 1002 (19.88 mm) and SI-64-017 and in the year 2012, clones 131/25, PN731, NZ1002, NZ1040, J799, NZ1140, J795 and V-311 recorded at par basal diameter with maximum recording clones.

Clone J799 recorded maximum mean volume index (Table 2) as well as volume index in the year 2011 (1169 cm^3), 2012 (17.59 cm^3), 2013 (17.59 cm^3), which was at par with clone SI-64-017 (2011:911.02 cm^3, 2012:1046 cm^3, 2013:1557 cm^3 with mean volume index of 1329 cm^3). As far as survival is concerned (Table1), in the year 2011 clones Kashmiri willow and NZ 1040 (97.9%) registered maximum survival, which was at par with other clones except clones J799 (87.5%), J172 (85.4%) and NZ 1179 (85.50%). In the year 2012 clone 131/25 showed best survival (97.9%) followed by clones J799, Austree and NZ1140 (95.83%). In the year 2013 clones J799 and NZ1179 recorded maximum survival (97.9%). Average plant survival was recorded maximum in the clones 131/25 and J799 (93.8%), which was at par with other clones except in clone J194 (72.20%). The differences in plant survival among the years may be ascribed to the difference in weather conditions particularly rainfall (Fig. 1b). Rainfall received in the initial months (Feb.-May) in the year 2011 was more than 2012 and 2013. In the present study, stem cuttings were raised under open nursery conditions, the environmental influence was reduced to minimal. Therefore, variation observed among the clones in morphological traits may be attributed to the genetic differences. Significant differences were also observed among provenances and clones of *Populus ciliata* (Singh and Devgiri, 1997, Sharma and Khurana, 2011), *P. deltoides* (Singh *et al.*, 2001) and *Salix* species (Singh *et al.*, 2012) for morphological traits in nursery. The significant difference in growth parameters observed among the years was due to the differences in weather conditions particularly rainfall pattern.

Genetic values: The genetic parameters furnished in Table 3 revealed that phenotypic coefficient of variation (PCV) is greater than genotypic coefficient of variation (GCV) for all growth parameters, which varied from 5.02 and 9.28 per cent in plant height in the year 2011 to 60.79 and 43.06 per cent in volume index in the year 2012, respectively. Maximum heritability (84.41 %) was found in basal diameter followed by plant height (70.27%), volume index (50.16 %) growth in the year 2012 and basal diameter in the year 2013. The genetic gain also recorded the same pattern as heritability with highest for basal area in the year 2012

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Table 1. *Details of Salix clones and plant survival in nursery*

S. No.	Clone	Species/hybrid	Source country/ originally developed	Plant survival (%)*			
				2011	2012	2013	Mean
1.	131/25	*S. babylonica x S. Alba*	UK/Argentina	89.6 (71.4)	97.9 (85.0)	93.8 (78.2)	93.8 (78.20)
2.	J172	*S. babylonica x S. alba x S.matsudana*	UK/China	85.4 (67.6)	89.6 (71.4)	93.8 (78.2)	89.6 (72.41)
3.	J-194	*S. matsudana x S.arbutifolia x S. Matsudana*	UK/China	93.8 (78.2)	64.6 (55.2)	58.3 (49.9)	72.2 (61.08)
4.	Austree	*S. matsudana x S. Alba*	UK/Newsland	93.8 (78.2)	95.8 (80.3)	75.0 (60.5)	88.2 (73.00)
5.	J-795	*S. matsudana x S. Alba*	UK/China	91.7 (73.4)	91.7 (76.6)	79.2 (63.1)	87.5 (71.03)
6.	J-799	*S. matsudana x S. Alba*	UK/China	87.5 (69.7)	95.8 (80.3)	97.9 (85.0)	93.8 (78.35)
7.	Kashmiri willow	*S. alba* cv. *Caerulea*	UK	97.9 (85.0)	89.6 (71.4)	83.3 (66.9)	90.3 (74.45)
8.	MB-368	*S. alba*	Croatia	91.7 (76.1)	87.5(70.4)	89.6 (71.4)	89.6 (72.30)
9.	NZ-1002	*S. matsudana x S. alba*	New Zealand	93.8 (78.2)	85.4 (71.4)	64.6 (53.8)	81.3 (67.80)
10.	NZ-1040	*S. matsudana x S. alba*	New Zealand	97.9 (85.0)	83.3 (66.6)	77.1 (61.4)	86.1 (71.03)
11.	NZ-1130	*S. matsudana x S. alba*	New Zealand	95.8 (83.0)	83.3 (71.3)	81.3 (73.7)	86.8 (75.07)
12.	NZ-1140	*S. matsudana x S.alba*	UK	89.6 (71.4)	95.8 (80.3)	81.3 (70.1)	88.9 (73.92)
13.	NZ-1179	*S. matsudana x S. alba*	UK	87.5 (69.7)	72.9 (58.9)	97.9 (85.0)	86.1 (71.21)
14.	PN-721	*S. matsudana x S. alba*	New Zealand	95.8 (80.3)	79.2 (64.0)	91.7 (76.6)	88.9 (73.62)
15.	PN-722	*S. matsudana*	New Zealand	93.8 (78.2)	83.3 (70.4)	89.6 (75.1)	88.9 (74.58)
16.	PN-731	*S. nigra*	New Zealand/USA	93.8 (78.2)	87.5 (73.8)	77.1 (62.0)	86.1 (71.03)
17.	SE-63-016	*S. jessoensis*	Italy/Japan	91.7 (76.1)	91.7 (76.6)	62.5 (52.6)	81.9 (68.44)
18.	SI-63-007	*S. alba*	Italy	93.8 (78.2)	81.3 (68.6)	89.6 (75.1)	88.2 (73.97)
19.	SI-64-017	*S. alba*	Italy	93.8 (78.2)	87.5 (69.7)	70.8 (57.4)	84.0 (68.44)
20.	V-311	*S. alba*	Croatia	95.8 (80.3)	89.6 (71.8)	60.4 (52.8)	81.9 (68.28)
	Mean			92.7 (76.8)	86.6 (71.7)	80.7 (67.4)	86.7 (71.98)
	$CD_{(0.05)}$	Year					3.96
		Clone					10.22
		Year x Clone					17.71

*Values in parentheses are arc sine transferred

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Table 2. Nursery growth performance of *Salix* clones the years 2011-13

Clone	Plant height (cm)				Basal diameter (mm)				Volume index (cm^3)			
	2011	2012	2013	Mean	2011	2012	2013	Mean	2011	2012	2013	Mean
131\25	275.67	360.94	338.01	324.87	15.11	16.09	17.53	16.25	634.87	968.51	1099.0	900.70
J172	298.67	258.69	317.56	291.64	13.44	11.65	14.81	13.30	558.16	371.78	728.37	552.77
J194	268.67	242.00	276.88	262.51	15.28	11.30	15.23	13.94	630.96	368.55	752.23	583.91
Austree	269.67	264.50	317.36	283.84	13.54	12.25	15.3	13.70	497.94	441.54	795.23	578.24
J795	299.00	398.27	368.81	355.36	13.13	14.91	16.85	14.97	522.33	916.20	1144.0	860.87
J799	347.00	396.88	425.76	389.77	17.47	15.22	19.88	17.52	1069.0	1160.0	1759.0	1329.0
Kashmiri	296.33	296.71	375.10	322.71	15.18	13.72	17.63	15.51	686.36	682.05	1233.0	867.25
MB-368	267.33	296.62	289.07	284.34	12.79	11.18	12.03	12.00	438.34	384.05	496.39	439.59
NZ-1002	299.33	347.04	388.49	344.95	14.51	15.48	19.48	16.49	652.40	877.54	1514.0	1015.0
NZ-1040	280.33	341.91	324.03	315.42	13.37	15.47	14.39	14.41	511.80	892.09	780.15	728.01
NZ-1130	282.00	282.84	337.29	300.71	14.02	12.33	15.70	14.02	564.43	496.78	864.45	641.89
NZ-1140	274.33	314.81	340.33	309.83	15.39	15.17	17.78	16.11	652.60	856.99	1133.0	880.84
NZ-1179	281.00	230.10	318.76	276.73	13.60	10.58	14.66	12.95	525.07	318.96	664.70	502.91
PN721	258.00	289.92	348.76	298.89	13.80	13.71	16.53	14.68	505.68	606.48	1062.0	724.68
PN-722	278.33	261.57	299.58	279.85	15.09	13.27	15.62	14.66	644.04	495.77	726.06	622.96
PN-731	301.00	262.83	283.56	282.46	12.58	15.75	16.22	14.85	490.39	757.14	864.38	703.97
SE-63-016	309.00	308.36	347.43	321.60	15.54	13.97	17.34	15.62	751.00	771.04	1248.0	923.21
SI-63-007	275.67	302.16	348.67	308.83	13.33	14.02	16.42	14.59	492.09	656.73	1023.0	723.90
SI-64-017	285.00	324.53	366.28	325.27	17.69	16.28	19.00	17.66	911.02	1046.0	1557.0	1171.0
V-311	279.00	294.89	343.94	305.94	14.35	14.17	16.62	15.05	583.18	676.45	1010.0	756.59
Mean	286.27	303.78	337.78	309.28	14.46	13.85	16.45	14.91	616.06	687.36	1023.0	775.37
$CD_{(0.05)}$												
Year	17.77				0.66				99.26			
Clone	45.88				1.72				256.28			
Year x Clone	NS				NS				NS			

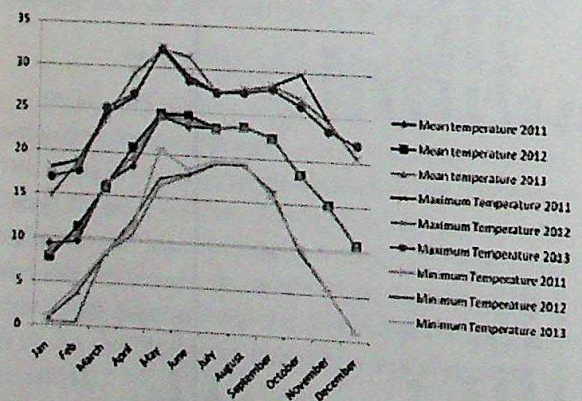

Fig. 1a. Temperature of experimental site

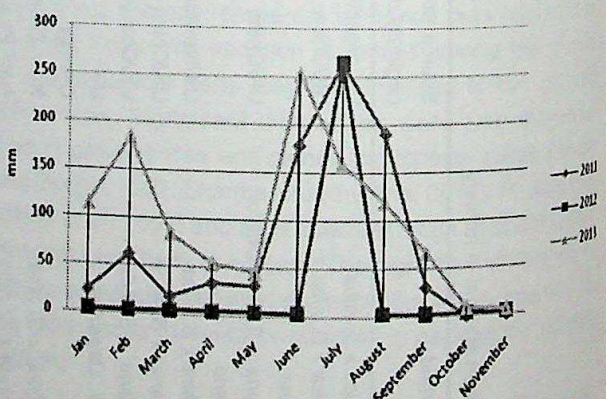

Fig. 1b. Rainfall in different years

(64.82) and lowest for plant height in the year 2011 (5.60%). The result shows the scope for improvement in these characters through clonal selection and control breeding. These results related to genetic parameters are in line as projected by Lin and Zsuffa (1993). High heritability estimates for height, basal diameter and survival are in line with the result obtained in in *Populus trichocarpa* (Heilman and Stettler, 1985), *P. deltoides* (Singh *et al.*, 2001) and *Salix* clones (Singh *et al.*, 2012; Huse *et al.*, 2008).

A significant positive correlation was observed between mean basal diameter and mean volume index (0.965) followed by basal diameter in 2013 and mean basal diameter (0.95) and basal diameter and volume index in the year 2013 (0.947). Present findings are in agreement with earlier results of Singh *et al.* (2012) in *Salix* clones.

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Table 3. Genetic factors of nursery growth of willow clones

S. No.	Genetic Parameter	Plant height (m)			Basal diameter (cm)			Volume index (cm^3)		
		2011	2012	2013	2011	2012	2013	2011	2012	2013
1.	Genetic variance	207.89	8696	924.03	1.54	18.13	2.53	16210.25	71027.59	72358.60
2.	Environmental variance	501.55	3679	3834.94	2.03	3.35	2.64	30831.76	70565.28	102924.50
3.	Phenotypic variance	709.43	12376	4758.97	3.57	21.48	5.17	47042.01	141592.86	175283.10
4.	Genotypic coefficient of variation (%)	5.02	33.89	10.04	8.53	33.94	9.72	20.31	43.06	26.67
5.	Phenotypic coefficient of variation (%)	9.28	40.43	22.79	13.00	36.94	13.90	34.60	60.79	41.52
6.	Environmental coefficient of variation (%)	7.80	22.05	20.46	9.80	14.59	9.93	28.01	42.91	31.81
7.	Heritability (%)	29.30	70.27	19.42	43.12	84.41	48.92	34.46	50.16	41.28
8.	Genetic advance	16.08	161	27.59	1.68	8.06	2.29	153.96	388.84	356.03
9.	Genetic gain	5.60	58.53	9.12	11.54	64.23	14.01	24.56	62.82	35.31

CONCLUSION

In the resent findings, significant differences were observed in *Salix* clones among different years in nursery. The clone x year interaction was found non-significant except for plant survival. The growth of plants was recorded highest in the year 2013. Significant and positive correlation was observed between basal diameter and volume index. However, the selected clones will have to be tested in the field conditions to find the genotype x environment interaction and to identify the best suitable clones for different agro-ecological regions.

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Indian Journal of Ecology

Plant growth, Yield and Fruit Quality of Kinnow Mandarin on Ten Rootstocks

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Abstract: The effects of various rootstocks on vegetative growth, fruit quality, yield and yield efficiency of Kinnow mandarin variety was evaluated under the ecological conditions of Punjab during 2014. Canopy volume was the lowest for trees on CRH-12 and was maximum on Volkameriana. Most smooth union was noted on rough lemon followed by Carrizo. The trees on NRCC-2 were the most efficient in yield per cubic meter of canopy volume. The largest fruit size was obtained from the trees on NRCC-5. The highest total soluble solids and acidity were recorded on Carrizo followed by CRH-12. Yield per tree was the highest on Volkameriana, followed by NRCC-2 and NRCC-6 rootstocks. Trees on CRH-12 were least productive.

Key Words: Citrus, rootstocks, Kinnow, fruit yield, fruit quality, tree size

Citrus rootstocks have well-known effects on tree vigour, size, yield, fruit size and various quality factors (Wutscher, 1979; 1988). Rootstocks have been characterized according to the rate of vegetative development of tree's canopy on a particular rootstock, and scion precocity and productivity (Castle *et al.*, 1993). The necessity of using rootstocks for citrus fruits is to have a profitable production against some limiting factors such as climate, bad soil conditions, diseases, etc. Besides these factors, use of the citrus rootstocks provides a large amount of choices to the growers to increase fruit quality and yield, obtain early fruiting, uniform cropping, avoidance of juvenility, control of the tree size and have the opportunity for high density planting, etc. These factors offer a lot of economic advantages to the growers and as a result, the citrus fruits are the most produced fresh fruits in the world since several decades (Tuzcu *et al.*, 2005). Choosing a rootstock is an important decision and local climatic and soil conditions are important factors in rootstock selection. Although any citrus variety can be used as a rootstock, some of them are better suited to specific conditions than the others (Davies and Albrigo, 1994; Lawrence and Bridges, 1974). The ideal citrus rootstock must be compatible with the scion, be adaptable to the appropriate soil and climatic factors and should also improve one or more characteristics i.e., pest and disease resistance, cold tolerance, harvest date, internal and external fruit quality, yield and post-harvest quality. Ultimately, the value of a rootstock lies in its ability to improve production and/or quality of the fruit.

Likewise, a successful citrus cultivar must be adaptable to the harsh climate of Punjab (where high temperatures are often greater than 40°C), must be vigorous and must produce high yields of good quality fruit of marketable size. Kinnow as cultivar fits very well for the agro-climatic conditions of Punjab. Though Kinnow is highly successful cultivar but the main rootstock of Punjab rough lemon suffers due to its susceptibility to *Phytophthora* and poor quality of fruits produced on it. In order to overcome the problems associated with rough lemon, newly developed citrus rootstocks were introduced to determine growth performance, yield and fruit quality of Kinnow cultivar grafted on new rootstocks in comparison to well established rootstocks.

MATERIAL AND METHODS

The experiment was conducted in College Orchard of Department of Fruit Scince, Punjab Agricultrual University, Ludhiana (latitude 30° 53' N, longitude 75° 48' E; elevation 244 m). The soil is well drained deep alluvial which is common in Ludhiana. Ludhiana features a humid subtropical under the Köppen climate classification, with average maximum and minimum temperatures of 35.8 °C and 2.7 °C, respectively, and an annual rainfall of 733 mm. The plants were planted on flat beds in September 2010 and were irrigated by flood method. Distance between plants was 3 meter and between rows 6 meter, with a plant densiy of 220 tree/acre. The orientation of rows was north-south. The experimental design was randomized block design with five replicates and two trees per plot.

Kinnow (*Citrus nobilis* Lour X *Citrus deliciosa* Tenore) mandarin was budded on the following rootstocks (treatments): NRCC-1, NRCC-2 (Rough lemon X Troyer citrange), NRCC-3, NRCC-4 (Rough lemon X Trifoliate orange), NRCC-5 (Rough lemon X Troyer citrange), NRCC-6 (Rough lemon X Trifoliate orange], CRH-12, Carrizo citrange [*Citrus sinensis* (L.) Osbeck×*P. trifoliata*], Rough

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lemon (*Citrus jambhiri* Lush) and Volkameriana [*Citrus volkameriana* (*L.*)]. NRCC series of rootstocks have been developed by National Research Centre on Citrus, Nagpur for their suitability to Indian agro-climatic conditions, similarly, CRH-12 has been developed by Indian Institute of Horticultural Research, Bangalore.

Standard culture techniques were used with mechanical weed control between rows and chemical control between trees. In the first three years of culture, trees were slighty pruned to give proper shape and remove sprouts from rootstock. In the fourth year no pruning was done. The experiment was managed according with regular cultural practices and fertilization schedule followed for Kinnow as per recommendation of Punjab Agricultural University. The experimental orchard was surrounded by several other citrus evaluation experiments.

Data on different fruit characters was recorded in January 2014. Tree height was measured from soil level to the top of the tree. Scion girth was measured in centimetres with the help of measuring tape at a height of 5.0 cm from the bud union and stock was measured 5.2 cm below the union. The canopy spread was measured in meters. Two readings were taken for tree spread in each replication and average was calculated. To measure canopy volume, tree was assumed to be one half of prolate spheroid (Jahn, 1979; Morse and Robertson, 1987) and volume was calculated by the equation: volume = 0.524 x height x width^2. Fifteen fruits were randomly selected from each tree for physico-chemical analysis. Fruit weight was measured with a scale sensitive to 0.01 g. Chemical analysis of the juice was carried out as previously reported by D'Aquino and Palma (2003) and included acidity expressed as grams of citric acid in 100 ml of juice, and total soluble solids (TSS) expressed as degrees Brix and TSS/acid ratio was calculated. The number of fruits born on each tree was counted manually. Fruit yield was measured at the time of harvest using scale sensitive to 1g. Yield efficiency was calculated by dividing the yield per tree with tree volume and data were suitably analyzed statistically.

RESULTS AND DISCUSSION

The rootstock clearly affected plant growth. The rootstock that produced the most vigorous Kinnow mandarin plants were Volkameriana, Rough lemon and Carrizo (Table 1). The plants in vigorous category had plant height in the range of 2.47 to 2.74 m, plant spread varied from 2.23 to 2.33 m and canopy volume ranged from 6.27 to 7.78 m^3. Intermediate vigour in Kinnow mandarin was induced by NRCC-2, NRCC-3, NRCC-4 and NRCC-6. Intermediate vigour category plant height ranged from 2.49 to 2.59 m, plant spread varied from 1.89 to 2.01 m and canopy volume ranged from 4.82 to 5.35 m^3. Canopy volume of Kinnow plans was reduced by two to three times by dwarfing rootstocks as compared to Rough lemon rootstock. The rootstocks that were least vigorous were NRCC-5, NRCC-1 and CRH-12. The canopy volume in dwarfing rootstocks varied from 1.80 to 3.03 m^3, plant spread was from 1.37 to 1.60 m and plant height ranged from 1.69 to 2.26 m. The results obtained regarding canopy volume are in agreement with those of Georgiou (2009) on Lapithkiotiki lemon, who reported that the highest volume was on sour orange and the lowest on Carrizo citrange.

Rootstocks significantly affected rootstock circumference, scion circumference and stock to scion ratio (Table 1). The scion circumference was the highest in Volkameriana, closely followed by Rough lemon. There was no significant difference in the scion circumference on rootstocks in categories vigorous and intermediate vigour. Scion girth in dwarf category ranged from 16.01 to 18.04 cm, rootstocks of this category viz. NRCC-5, NRCC-1 and CRH-12 were at par for scion circumference. However, the dwarfing rootstocks had significantly lower scion circumference as compared to vigorous rootstocks. Similar trend was observed for rootstock circumference. This study get support from the findings of Perez-Perez *et al.* (2005) who mentioned that trunk cross sectional area of three lemon varieties on sour orange was larger than that of trees on *Citrus macrophylla*. In addition, Georgiou (2009) reported that the highest trunk cross sectional area in Lapithkiotiki lemon was recorded on sour orange and the lowest on Carrizo citrange.

The Kinnow trees budded on NRCC-3 had significantly higher stock to scion ratio than those on other rootstocks. The lowest ratio was found with rough lemon followed by Carrio citrange and Volkameriana, indicating similar growth rate of scion and rootstock. High ratio indicates dissimilarity in growth rate of rootstock and scion as in NRCC-3 rootstock. Similar results were reported by several researchers (Georgiou and Gregoriou, 1999; Perez-Perez *et al.*, 2005; Bassal, 2009; Georgiou, 2009).

Fruit quality: The rootstocks significantly influenced fruit weight (Table 2). Fruits from trees on NRCC-5 were significantly heavier than those from the other rootstocks, except NRCC-3, which was at par. The lightest fruits were obtained from the trees on NRCC-6 followed by NRCC-1. Also, Mendilcioglu (1986) on Satsumas found that Troyer and Carrizo citranges had heavier fruits when compared to sour orange. Similarly, the biggest fruits were found in Kütdiken lemon trees grafted on Yuzu, Volkameriana and Taiwanica, whereas, the smallest fruits were obtained from

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Table 1. Growth performance of Kinnow mandarin on different rootstocks

Rootstocks	Plant height (m)	Plant spread (m)	Rootstock girth (cm)	Scion girth (cm)	Stock: scion ratio	Canopy volume (m^3)
NRCC-1	1.69	1.43	19.33	16.01	1.21	1.80
NRCC-2	2.55	2.01	27.14	22.30	1.22	5.35
NRCC-3	2.55	1.92	29.57	22.24	1.33	4.92
NRCC-4	2.59	1.89	28.70	23.15	1.24	4.82
NRCC-5	2.26	1.60	21.48	18.04	1.19	3.03
NRCC-6	2.49	1.96	27.99	22.94	1.22	5.01
CRH-12	2.02	1.37	20.02	16.82	1.19	1.98
Carrizo	2.47	2.23	25.06	21.74	1.15	6.27
Rough lemon	2.74	2.33	27.69	24.61	1.13	7.78
Volkameriana	2.64	2.27	31.41	25.66	1.22	7.08
SEm±	0.12	0.13	1.64	1.36	0.02	0.70
LSD at 5%	0.41	0.43	5.41	4.50	0.05	2.30

the trees on Benecke trifoliate orange and T. citrange by Tuzcu *et al.* (1992). The effect of rootstocks on fruit length and fruit diameter was not statistically significant and all of the rootstocks gave similar values (Table 2).

Kinnow mandarin quality was significantly dependent upon the rootstock used. Fruits on Carrizo had significantly higher total soluble solids (TSS) than all other rootstocks, except CRH-12. The lowest TSS was recorded on NRCC-5 rootstock followed by NRCC-4 and NRCC-1 rootstocks. Carrizo resulted in about 10 per cent higher TSS in Kinnow than that recorded on rough lemon. Similarly, soluble solids of fruits from trees on Carrizo citrange was recorded to be more than 20 per cent higher than that of fruits from rough lemon (Wutscher, 1988; Barry and Castle, 2004). No other factor had such a large effect on soluble solids contents as rootstock (Barry, 2000; Barry *et al.*, 2000; 2003). While explaining that juice quality differences of fruit from trees borne on different rootstocks, Gardner (1969) concluded that the tree foliage supplies carbohydrates to fruit, but rootstock determines the amount. Although it is unclear how rootstocks exert their influence on juice quality in *Citrus* spp., plant water relations, mineral nutrition and phytophormones have been proposed as being among the most important factors involved (Castle, 1995).

Fruit juice acidity of Kinnow mandarin was affected significantly by the rootstocks used (Table 2). The fruits containing the highest acid were produced on CRH-12 followed by Carrizo and NRCC-5. The lowest acidity was recorded on NRCC-1. These results are in agreement with previous works, where juice acidity of scion has been found to be significantly influenced by rootstock used (Kaplankiran *et al.*, 2005b; Georgiou, 2009).

Fruit quality: The rootstocks differed considerable in their ability to influence fruit yield and quality (Table 2). Maximum fruit number per tree was counted on Volkameriana and it was significantly higher than the fruit number recorded on most commonly used rootstock in Punjab i.e. Rough lemon. Similarly, high fruit number was recorded on NRCC-2 and NRCC-6 rootstocks and both these stocks were at par with Volkameriana. Trees on CRH-

Table 2. Fruit quality of Kinnow mandarin on different rootstocks

Rootstocks	Fruit weight (g)	Fruit length (cm)	Fruit dia. (cm)	TSS (°Brix)	Acidity (%)	Fruit number $Tree^{-1}$	Yield (kg $tree^{-1}$)	Yield efficiency (kg m^{-3})
NRCC-1	203.5	6.5	7.7	9.6	0.72	76.9	15.6	8.68
NRCC-2	205.8	6.4	7.8	10.8	0.78	281.1	57.8	10.81
NRCC-3	218.1	6.6	8.0	10.7	0.75	213.4	46.5	9.47
NRCC-4	214.3	6.5	7.9	9.4	0.77	212.2	45.5	9.43
NRCC-5	224.0	6.6	7.7	9.3	0.81	57.3	12.8	4.23
NRCC-6	195.3	6.3	7.5	10.4	0.75	256.9	50.2	10.02
CRH-12	211.0	6.6	7.8	11.3	0.84	17.5	3.7	1.86
Carrizo	216.6	6.6	8.0	11.7	0.82	182.6	39.6	6.31
Rough lemon	209.8	6.4	7.8	10.6	0.78	196.0	41.1	5.28
Volkameriana	211.1	6.6	7.7	10.6	0.77	323.8	68.4	9.65
S Em±	2.34	0.03	0.04	0.23	0.01	28.9	6.0	1.01
LSD at 5%	7.36	NS	NS	0.7	0.04	91.0	18.8	3.33

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12 had the lowest number of fruits per tree followed by NRCC-5. Similar trend was recorded for harvested fruit yield per tree. The results obtained regarding productivity are in agreement with Levy (1986) and Al-Jaleel *et al.* (2005) who reported significant differences among the rootstocks for yield per tree.

In the first year of fruiting, significant differences were recorded for yield efficiency of Kinnow mandarin on different rootstocks (Table 2). Trees on NRCC-2 produced the most fruit yield per unit canopy volume followed by NRCC-6 and Volkameriana. These three rootstocks were at par for yield efficiency. The trees on CRH-12 were the least productive, all other rootstocks produced more than 4 kg fruit per cubic meter of canopy. Differences in yield efficiency on different rootstocks have also been observed by Demirkeser *et al.* (2009) and Georgiou (2009).

Conclusively, rootstocks showed significant effects on plant growth, fruit quality, yield and yield efficiency. Many of rootstocks differ considerably from the main rootstock of Punjab i.e. Rough lemon. In the coming years there is high probability of selecting some good rootstock for this region from this trial.

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Availability of Lead as Influenced by Contamination Levels, Ageing and Amendment Regimes

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Abstract: A laboratory incubation study was conducted to investigate the effect of time and some soil characteristics on the availability of added lead. Three levels of Pb viz. 0, 20 and 200 mg Pb kg^{-1} soil were added through aqueous lead acetate $(CH_3COO)_2$ Pb $3H_2O$) to soils having different pH, organic matter, $CaCO_3$ and clay content. The treated soil samples were incubated for 0, 14 and 28 days at 25ºC and analyzed for DTPA-Pb. The results indicated that there was a linear decrease in the availability of Pb with ageing but the decrease varied with level of contamination. At zero period of incubation and no contamination minimum per cent recovery of added Pb was obtained with the addition of 5% lime and at 14 and 28 days it was obtained with the addition of 2 % FYM and 40 % finer fraction, respectively. In case of contamination at 20 mg Pb kg^{-1} soil the characteristics which curtailed maximum extraction were 2% FYM, pH 9.5 and 5% lime at 0, 14 and 28 days after incubation, respectively and at 200 mg Pb kg^{-1} soil it was 5% lime, 2% FYM and 40% finer fraction, respectively. The results enable us to understand the sink capacity of soils varying in characteristics.

Key Words: Lead, soil, incubation, contamination, characteristics, availability

Lead (Pb) is one of the major heavy metals that have gained considerable importance as a potent environmental pollutant (Sharma and Dubey, 2005). Apart from the natural weathering processes, Pb contamination of the environment has resulted from mining and smelting activities, Pb containing paints, gasoline and explosives as well as from the disposal of municipal sewage sludges enriched in Pb (Chaney and Ryan, 1994). Despite regulatory measures adopted in developed and industrialized countries to limit Pb input in the environment, it continues to be one of the most serious global environmental and human health hazard but more so in developing countries. As many of the Pb pollutants are indispensable for modern human life, soil contamination with Pb is not likely to decrease in the near future (Yang *et al.*, 2000). Significant increase in the Pb content of cultivated soils receiving sewage irrigation has been observed in industrial cities. It tends to accumulate in the surface ground layer and its concentration decreases with soil depth (Sikka, 2003). Lead concentration in soil solution is of great importance because plants are likely to take up labile metal from soil solution. Although Pb is not essential for plant growth, it is readily absorbed by plants in varying amounts depending upon its bioavailability in the soil. It inhibits photosynthesis, upsets mineral nutrition, water balance, changes hormonal status and affects membrane structure and permeability (Sharma and Dubey, 2005).

It is necessary to develop techniques to treat and stabilize heavy metals *in situ* in an effective manner. An approach towards this is to render the metals immobilized by altering some physico-chemical properties of soils using different amendments. Lime, phosphates, or organic matter residues are commonly employed for metal immobilization in soils (Ruby *et al.*, 1999). Lime is often chosen because it changes the forms of the metals by rendering them less bioavailable. Organic matter in soil strongly influences the bio-availability of heavy metals. Addition of farmyard manure may be a strategy to reduce the accumulation of metals in edible crops (McBride, 1994). However, Sidhu and Narwal (2006) suggested that the efficiency of the organic material in reducing metal uptake was generally small. On the contrary, Jin *et al.* (2005) found that addition of manure increased heavy metal uptake by plants. Therefore, we thought it imperative to investigate the effect of time and some soil characteristics on retention and availability of a range of lead contamination. We carried out an incubation study with a loamy sand soil, the characteristics of which were altered by modifying soil pH, addition of lime, organic matter and finer fraction. Extraction of Pb was estimated for different time periods.

MATERIALS AND METHODS

Surface soil sample was collected from a loamy sand soil. The original properties of the soils were altered by the addition of different rates of lime ($CaCO_3$), organic matter, and finer fraction (silt + clay) and by changing the pH of the soil (Table 1). The basic characteristics of soil were pH 7.65, OC 0.21%, $CaCO_3$ 0.14% and silt + clay 16.1%. The soil samples were mixed with 2.5 and 5% Analar grade $CaCO_3$, , well rotten and ground FYM@ 1 and 2.0% and 20 and 40% silt plus clay separated from a clay loam soil and 0.5 N NaOH and 0.5 N HCl to obtain pH levels of 5.5, 7.5 and 9.5. The treated soils were kept at room temperature at field

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Table 1. Physico-chemical characteristics of incubated soils following treatment with $CaCO_3$, organic matter, clay + silt and pH

Treatments		pH	Organic carbon (%)	$CaCO_3$ (%)	Silt + clay (%)
pH	5.5	5.42	0.21		
	7.5	7.62	0.20		
	9.5	9.38	0.21		
$CaCO_3$ (%)	2.5	8.22	0.20	2.42	
	5.0	8.51	0.19	4.91	
FYM(%)	1.0	7.67	0.43		
	2.0	7.61	0.63		
Clay + silt (%)	20	8.07	0.27	0.42	32.7
	40	8.17	0.36	0.55	53.8
Control soil		7.65	0.21	0.14	16.1

capacity for 30 days for stabilization and analysed for their final characteristics (Table 1). Standard analytical procedures were adopted for the determination of $CaCO_3$ (Puri, 1950), organic carbon (Walkley and Black, 1934), soil texture and pH (Jackson, 1973). Twenty five gram soil samples so prepared were kept in polythene bottles. The soil samples with different characteristics were treated in duplicate with 0, 20 and 200 mg Pb kg^{-1} soil added through aqueous lead acetate $(CH_3COO)_2$ Pb $3H_2O$) and kept in an incubator at 25° ± 1° C and maintained at field capacity for 28 days and the loss of moisture was compensated by adding distilled water after every second day. The treated soils after the addition of metal were drawn after 0, 14 and 28 days and were analyzed for DTPA-extractable Pb (Lindsay and Norvell, 1978) using Atomic Absorption Spectrophotometer (Model: Varian Spectra AA 20 plus). Farm yard manure was analysed by digesting two grams of oven dried FYM in 20 ml of distilled concentrated nitric acid at low heat on a hot plate to oxidize organic matter and digested the mixture with 20 ml of perchloric acid until dense white fumes of acid appeared and was analysed for various metals (Table 2).

Table 2. Chemical composition of oven dried farm yard manure

Composition	Content
Organic Carbon (%)	21.54
pH (1:4 water extract)	7.89
EC (dS/m)	4.15
Fe (mg kg^{-1} soil)	1795
Mn	205
Zn	60.5
Cu	10.5
Pb	0.52

RESULTS AND DISCUSSION

Effect of calcium carbonate on DTPA-Pb: The addition of lime ($CaCO_3$) and increase in period of incubation decreased the extractability of applied Pb (Table 3). Addition of 2.5 and 5% lime in 20 mg Pb kg^{-1} soil treatment decreased DTPA - Pb from 13.8 in control to 12.4 and 12.0 mg Pb kg^{-1} soil, respectively at zero period of incubation and the corresponding decrease at 14 and 28 days of incubation was from 12.0 in control to 9.92 and 8.23 mg Pb kg^{-1} soil and from 9.4 to 6.3 and 4.24 mg Pb kg^{-1} soil, respectively.

At 200 mg Pb kg^{-1} soil the respective decrease in DTPA-Pb extraction was 7.9 and 15.8 mg Pb kg^{-1} soil in 2.5 and 5% lime treatments over control at zero time of incubation and the corresponding value decrease at 14 and 28 days were 11.4, 16.2 and 2.8, 13.1 mg Pb kg^{-1} soil, respectively. So, maximum decrease in absolute terms (16.2 mg Pb kg^{-1} soil) was registered after 14 days of incubation in 5% lime treated soil receiving 20 mg Pb kg^{-1} soil. The extent of decrease in DTPA Pb at 2.5 and 5% level of lime was minimum in soil receiving 200 mg Pb kg^{-1} soil after 28 days of incubation and was found to be 2.8 and 13.1 mg Pb kg^{-1} soil over control, respectively.

Irrespective of reaction period, the mean DTPA-Pb in 20 mg Pb kg^{-1} soil treatment decreased by 2.16 and 3.52 mg Pb kg^{-1} soil, respectively at 2.5 and 5% lime addition over control. However, at 200 mg kg^{-1} Pb addition the mean values decreased by 7.4 and 15.1 mg Pb kg^{-1} soil at 2.5 and 5% lime addition over control. The values of DTPA-Pb, irrespective of $CaCO_3$ lime treatment decreased by 2.71 and 5.89 mg Pb kg^{-1} soil over control at 20 mg Pb kg^{-1} soil after 14 and 28 days of incubation, respectively and the corresponding decrease was 25.3 and 72.2 mg kg^{-1} soil at 200 mg Pb kg^{-1} soil.

This indicated that the period of contact of the added metal with the soil and the amount of lime are important factors that control the extractability of Pb in soils. The decrease in DTPA-Pb in soil with the addition of lime may be attributed to the stronger binding of it with $CaCO_3$, precipitation by $CaCO_3$ and rise in pH of the soils by addition

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Table 3. Influence of lime ($CaCO_3$) and incubation period on DTPA - Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time (days)	Levels of $CaCO_3$ (%)			Mean
		0.14	2.42	4.91	
0	0	0.62	0.57	0.52	0.57
	14	0.60	0.58	0.52	0.57
	28	0.60	0.50	0.50	0.53
	Mean	0.61	0.55	0.51	
20	0	13.80	12.40	12.08	12.76
	14	12.00	9.92	8.23	10.05
	28	9.40	6.30	4.24	6.65
	Mean	11.73	9.54	8.18	
200	0	142.60	134.70	126.80	134.70
	14	118.60	107.20	102.40	109.40
	28	67.80	65.00	54.70	62.50
	Mean	109.67	102.30	94.63	

of lime. The rapid fall in extractable Pb with time of incubation indicated that Pb takes time to react with soil and within 28 days more than 60 per cent of this change into unavailable forms. Ma and Uren (1998) observed that the proportion of recently added Pb in the DTPA-extractable fraction decreased markedly with time. They also observed that addition of lime decreased the extractability of added Pb through its effect on increase in pH. In the present study also there was an increase in pH of the soil. So, this increased pH and formation of $CaCO_3$.$PbCO_3$ kind of insoluble products might have curtailed the extractability of added Pb in soil.

Effect of organic matter on DTPA-Pb: At both the levels of added Pb, the content of DTPA-Pb decreased with the addition of organic matter (Table 4). The contents decreased from 12.02 in control to 10.5 and 10.0 mg Pb kg^{-1} soil at 14 days after incubation and from 9.4 in control to 5.2 and 5.05 mg kg^{-1} at 28 days after incubation in 1 and 2% FYM addition, respectively. The mean DTPA-Pb decreased from 11.7 in control to 9.03 mg Pb kg^{-1} soil with 2% FYM addition and from 13.14 at zero period of incubation to 6.55 mg Pb kg^{-1} soil after 28 days of incubation.

Similarly, considerable reduction in DTPA-Pb was observed at 200 mg Pb kg^{-1} soil. It decreased from 142.6 in control to 130 mg Pb kg^{-1} soil with 2% addition of FYM at zero period of incubation and from 118.6 to 95.8 mg Pb kg^{-1} soil and from 67.8 to 50.1 mg Pb kg^{-1} soil after 14 and 28 days after incubation, respectively. So compared to 142.6 mg kg^{-1} DTPA-Pb in control at zero period of incubation it decreased substantially to 50.1 mg Pb kg^{-1} soil in 2% FYM treated soil, which was incubated for 28 days representing a decrease of 2.84 times.

It indicated that at higher levels, the organic constituents and the DTPA might be competing with each other for the same metal and the increase or decrease in metal extraction would be the resultant of the net effect of these two factors. The data indicated that at low organic

Table 4. Influence of organic matter and incubation period on DTPA - Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time (days)	Levels of $CaCO_3$ (%)			Mean
		0.14	2.42	4.91	
0	0	0.62	0.74	0.77	0.71
	14	0.60	0.76	0.69	0.68
	28	0.60	0.76	0.59	0.65
	Mean	0.61	0.75	0.68	
20	0	13.80	13.60	12.04	13.15
	14	12.00	10.50	10.00	10.83
	28	9.40	5.20	5.05	6.55
	Mean	11.73	9.77	9.03	
200	0	142.60	132.40	130.00	135.00
	14	118.60	104.80	95.80	106.40
	28	67.80	57.90	50.10	58.60
	Mean	109.67	98.37	91.97	

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Table 5. Influence of pH and incubation period on DTPA-Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time (days)	Levels of pH			Mean
		5.42	7.62	9.38	
0	0	0.80	0.64	0.48	0.64
	14	0.62	0.56	0.46	0.55
	28	0.62	0.54	0.46	0.54
	Mean	0.68	0.58	0.47	
20	0	15.70	14.00	12.20	13.97
	14	13.20	11.50	7.60	10.77
	28	10.20	10.00	5.40	8.53
	Mean	13.03	11.83	8.40	
200	0	148.40	140.20	140.20	142.9
	14	127.30	112.10	100.60	113.35
	28	72.80	70.90	57.80	67.83
	Mean	116.17	107.73	99.53	

matter content DTPA was efficient in extracting the chelated and adsorbed Pb but at higher levels of organic matter addition the efficiency of DTPA-Pb extraction decreased due to the formation of stable organo-metal complexes. Earlier, Bjerre and Schierup (1985) had reported that Pb is bound by organics and oxides and that despite the fact that organic soil the highest quantities of Pb the concentration and uptake of Pb, was lower in plants grown in organic soil compared with sandy soil. The extractability and plant uptake of Pb was found to be inversely related to the content of organic matter in soil, probably because of the increased capacity of the soil to adsorb metals (John *et al.*, 1972). Piccolo (1989) also found that humic substances in the organic matter efficiently immobilized soluble and exchangeable forms to a large extent in mineral soils and retention capacity was directly related to the amount of added humic substances and incubation period.

Effect of pH on DTPA-Pb: The data in Table 5 indicated that an increase in soil pH had a depressing effect on DTPA-Pb and vice-versa. The mean DTPA-Pb decreased from 0.68 mg Pb kg^{-1} soil in 5.5 pH soil to 0.58 and 0.47 mg Pb kg^{-1} soil in 7.5 and 9.5 pH, respectively, in soils where Pb was not applied externally. In 20 mg Pb kg^{-1} soil treatment the mean DTPA - Pb was 13.0, 11.8 and 8.4 mg Pb kg^{-1} soil at 5.5, 7.5 and pH 9.5, respectively indicating 35.4 per cent decrease at 9.5 pH as compared to pH 5.5. The mean values of DTPA - Pb at 0, 14 and 28 days of incubation were 13.97, 10.77 and 8.53 mg Pb kg^{-1} soil. The corresponding values at 200 mg kg^{-1} Pb addition were 116.2, 107.7 and 99.2 mg Pb kg^{-1} soil, respectively at soil pH of 5.5, 7.5 and 9.5 thus registering a 14.6 per cent decrease in the extractability of Pb at pH 9.5 as compared to pH 5.5. Mean DTPA-Pb also decreased substantially with incubation period from 142.9 mg kg^{-1} at 0 time of incubation to 113.35

Table 6. Influence of finer fraction and incubation period on DTPA-Pb (mg kg^{-1}) at different levels of Pb addition

Pb added	Incubation time (days)	Levels of finer fraction (%)			Mean
		16.1	32.7	53.8	
0	0	0.62	0.54	0.52	0.56
	14	0.60	0.49	0.49	0.53
	28	0.60	0.50	0.43	0.51
	Mean	0.61	0.51	0.48	
20	0	13.80	13.00	12.80	13.20
	14	12.00	9.80	10.00	10.60
	28	9.40	4.80	4.80	6.33
	Mean	11.73	9.20	9.20	
200	0	142.60	132.60	128.20	134.47
	14	118.60	109.90	100.60	109.70
	28	67.80	60.20	42.20	56.73
	Mean	109.67	100.90	90.33	

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and 66.83 mg Pb kg^{-1} soil at 14 and 28 days after incubation, respectively, indicating a corresponding decrease of 20.6 and 53.2 per cent, respectively over zero time of incubation. A maximum of 61.7 per cent decrease was recorded in DTPA-Pb at 9.5 pH and 28 days after incubation as compared to 5.5 pH and 0 period of incubation. Solution pH regulates the protonation and deprotonation of inorganic and organic COOH groups, thereby affecting the surface charge and the number of available sites in soils, minerals or organics for sorption of Pb and the ability of soils to sorb a metal is inversely related to the extent of extraction and availability of metals.

Cieslinski *et al.* (1996) reported that application of metal to soil significantly increased its extraction from soil but more was extracted at pH 5.1 than at pH 7.8 and was found to be more mobile in acid soils within a pH range of 4.5 to 6.5, whereas, it was more readily adsorbed by soil particles and bound by organic compounds when soil pH was increased. The stability constant of organic matter metal complexes increased with increasing pH as a result of increased ionization of functional groups especially COOH with increasing pH (Stevenson and Ardakani, 1992).

Effect of finer fraction on DTPA-Pb: At 20 mg kg^{-1} of added Pb the mean DTPA-Pb decreased to 2.53 mg Pb kg^{-1} soil over 11.73 mg Pb kg^{-1} soil in control when 20 and 40 per cent of finer fractions were added to the original soil (Table 6). Increasing the rate of Pb to 200 mg kg^{-1} soil the mean values of DTPA-Pb, irrespective of the incubation period were 109.7, 100.9 and 90.3 mg Pb kg^{-1} soil in untreated control and with 20 and 40 per cent of added finer fractions, respectively.

The increase in incubation period also decreased the DTPA-Pb in soils. Mean decrease in DTPA-Pb at 14 and 28 days of incubation over the start of incubation period irrespective of the addition of finer fractions was 5.4 and 8.9, 19.7 and 52.0 and 18.4 and 57.8 per cent at 0, 20 and 200 mg Pb kg^{-1} soil, respectively. The mean DTPA-Pb content irrespective of the rate of Pb application and added finer fractions was 48.1, 40.3 and 21.2 mg Pb kg^{-1} soil at incubation period of 0, 14 and 28 days, respectively.

The silicate clay minerals are known to have permanent and pH dependent charge sites. Permanent charges arise due to isomorphous substitution in the crystal lattice while pH dependent charges are assumed to be located on carboxyl and hydroxyl groups formed on the broken crystal edges. The heterogeneous nature of the negative charge associated with clay minerals is illustrated by variation in the observed cation preference, variation with cation

Table 7. Per cent recoveries of 20 and 200 mg Pb kg^{-1} soil as affected by soil characteristics and incubation period

Soil Characteristic	Incubation period (days)		
	0	14	28
		20 mg Pb kg^{-1} soil	
2.5% $CaCO_3$	62.0	49.6	31.5
5% $CaCO_3$	60.4	41.2	21.2
1% Organic matter	68.0	52.5	26.0
2% Organic matter	60.2	50.0	25.2
20 % Finer fraction	65.2	49.0	24.0
40% Finer fraction	64.0	40.0	24.0
5.5 pH	78.5	66.0	51.0
7.5 pH	70.0	57.5	50.0
9.5 pH	61.0	38.0	27.0
Control soil	69.0	60.0	47.0
		200 mg Pb kg^{-1} soil	
2.5% $CaCO_3$	67.3	53.6	32.5
5% $CaCO_3$	63.4	51.2	27.3
1% Organic matter	66.2	52.4	28.9
2% Organic matter	65.0	47.9	25.0
20 % Finer fraction	66.3	54.9	30.1
40% Finer fraction	64.1	50.3	21.1
5.5 pH	74.2	63.6	36.4
7.5 pH	70.1	56.1	35.4
9.5 pH	70.1	50.3	28.4
Control soil	71.3	59.3	33.9

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concentration, surface saturation and pH (Inskeep and Baham, 1983). Ziper *et al.* (1988) observed that there are three possible locations on clay minerals viz. external planar, interlayer and edge surfaces where cation can be sorbed by ion exchange. The decrease in DTPA extractable Pb may be due to increase in the surface area which enhanced sorption of Pb as compared to control soil where a large part of the metal may have remained unadsorbed from the soil solution. The decrease in the extractability of Pb with increase in incubation period has been attributed to the greater contact of these metals with solid surfaces, which might have resulted in their greater fixation. Ziper *et al.* (1988) also reported that edges and high charge density planar sites contribute the greatest influence on metal extraction. They observed that increasing clay fraction resulted in an increase in edge to planar surface area ratio or the increase in edge to interlayer surface area ratio resulting in an enhanced sorption of metal. The relative retention of different metals by clays depends strongly on the kind of clay surface and the level of loading. In a study conducted by Gray *et al.* (1999), it was reported that pH was the most dominant soil variable affecting extractability of Cd in soil and sorption and desorption of native and added metal in soils of New Zealand followed by organic matter, clay content, cation exchange capacity and total soil metal. They also found that increasing organic matter, clay, CEC or pH resulted in a decrease in availability of metal and as was expected organic matter, clay and CEC were themselves found to be significantly correlated. It is clear from the above discussion that a range of soil properties control the extraction of Pb from soil.

Per cent recovery of added Pb as affected by soil characteristics and incubation periods: The per cent recovery of 20 mg kg^{-1} of added Pb was 69 in control soil and it decreased to 62, 68, 65.2 upon addition of 2.5% lime, 1% FYM and 20% finer fraction and further declined to 60.4, 60.2 and 64.0 per cent in 5% lime, 2% FYM and 40% finer fraction treated soil at zero time of incubation (Table 7). The per cent extraction, however, increased to 74.2 at pH 5.5 and decreased markedly to 61.0 at pH 9.5. Similarly, a considerable decrease in the per cent recovery of added Pb was observed at 14 and 28 days after incubation. A minimum recovery of 38.5 was observed in pH 9.5 soil at 14 days of incubation and 21.2 per cent for 5% lime treated soil at 28 days after incubation as compared to other treatments.

Similarly, a decrease in the per cent recovery of added Pb @ 200 mg Pb kg^{-1} soil was observed due to addition of lime, FYM and finer fraction at 0, 14 and 28 days after incubation. A minimum per cent recovery of added Pb was 63.4 with 5% lime at start of incubation, 47.9 with 2 % FYM at 14 days and 21.1 with addition of 40 % finer fraction at 28 days of incubation. The per cent recovery of added Pb decreased with rise in soil pH and its value at pH 5.5 and 9.5 were 74.2 and 71.1 at the start of incubation, 63.6 and 50.3 at 14 days and 36.4 and 28.4 at 28 days of incubation.

In case of 20 mg Pb kg^{-1} soil, the characteristics which curtailed maximum extraction were 2% FYM, pH 9.5 and 5% lime at 0, 14 and 28 days after incubation, respectively and at 200 mg Pb kg^{-1} soil it was 5% lime, 2% FYM and 40% finer fraction at 0, 14 and 28 days after incubation, respectively. So, specific soil characteristic was important in decreasing the availability of a Pb at a particular load of it in the soil.

Soil characteristics such as $CaCO_3$, organic matter, finer fraction and soil pH decreased the extraction of Pb from the soil due to formation of stable carbonate precipitates (Singh and Nayyar, 1989). Complexation of metals on the surface of solid organic matter or formation of stable organo-metal complexes (Deka *et al.*, 1997), protonation and deprotonation of inorganic and organic functional groups, which affect the surface charge and the number of available sites in soils, minerals or organics for sorption of Pb.

This investigation on effect of different soil characteristics provide useful information to know the mechanism of metal availability and the capacity of the soil to serve as a sink for Pb but the interdependence of these soil characteristics on one another needs to be carefully determined.

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Productivity of Gobhi Sarson (*Brassica napus* var. *napus*) and Oats Fodder (*Avena sativa* L.) Intercropping System in Relation to Planting Patterns and Row Spacing

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Abstract: Fifteen intercropping systems were evaluated in a randomized block design with four replications. The findings of this study indicated that growing of oats fodder as an intercrop in *gobhi sarson* did not show any adverse effect on the seed yield of gobhi sarson sown at 45 and 60 cm row spacing. All the intercropping systems recorded significantly higher gobhi sarson equivalent yield and net returns as compared to sole cropping systems. It was also observed that variety GSL 1 at 45, 60, 75 and 90 cm row spacing with oats as an intercrop at planting patterns of 1:1, 1:2, 1:2 and 1:3, respectively and GSC 6 at 60 and 90 cm row spacing with oats at planting patterns of 1:2 and 1:3, respectively can be grown for getting higher total productivity and net returns per unit area per unit time.

Key Words: Gobhi sarson, land equivalent ratio, intercropping systems, oats fodder

With increasing population and improving purchasing power of people, the demand of edible oil in the country is increasing at the rate of 4-6% per annum (Rao, 2009). There is very little chance for horizontal growth of the crop. Thus, the production of rapeseed and mustard can be increased by vertical growth of the crop through intercropping with other crops. Various *Brassica* species have been successfully intercropped with different crops *viz.* chickpea, lentil, sugarcane, potato, wheat, etc. under various agro-climatic zone of the country. Gobhi sarson is a new emerging oilseed crop having limited area of cultivation confined to Haryana, Punjab and Himachal Pradesh. It is a long duration and widely spaced row crop. Because of photo-sensitivity and thermo-sensitivity, this crop is slow growing at the initial stage and as a result it evades the frost. So, there is a scope of growing oats fodder as an inter crop during its early growth stages to increase productivity per unit land and per unit time. Oats is an important rabi fodder grown under restricted conditions and in Punjab, it is next to berseem in importance because it provides balanced diet for cattle when mixed with berseem. Keeping these points in view, the present study was undertaken to find out the optimum row spacing and suitable variety of gobhi sarson for intercropping system and to work out a suitable planting pattern for gobhi sarson + oats fodder intercropping system.

MATERIAL AND METHODS

The present study was carried out at Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana during 2012-13. The soil of the experimental site was loamy sand in texture with pH 7.8, electrical conductivity 0.32 dSm^{-1}, organic carbon 0.29%, low in available N (224.5 kg ha^{-1}) and medium in available P (20.5 kg ha^{-1}) and K (226.9 kg ha^{-1}). The experiment was laid out in a randomized block design with fifteen intercropping systems replicated four times. Gobhi sarson and oats fodder were sown on October 25, 2012 at optimum soil moisture using recommended seed rate. Two varieties of gobhi sarson viz. GSL 1 and GSC 6 were grown at row spacing of 45, 60, 75 and 90 cm. Oats fodder variety "Kent" was sown as an intercrop in different ratio as per treatments with row to row spacing of 20 cm. In gobhi sarson, the uniform plant stand was maintained with decrease in intra-row spacing. The plant to plant spacing was kept at 10, 7.5, 6 and 5 cm in row spacing of 45, 60, 75 and 90 cm, respectively. A uniform dose of 75 kg N ha^{-1}, 20 kg P_2O_5 ha^{-1} and 15 kg K_2O ha^{-1} was applied before sowing of gobhi sarson. Second dose of nitrogen at the rate of 75 kg ha^{-1} was applied after 30 days of sowing. The recommended dose of fertilizer for oats fodder @37.5 kg P_2O_5 ha^{-1} and 37.5 kg N ha^{-1} before sowing and 37.5 kg N ha^{-1} after first cutting were applied on area basis for all the treatments. Weeds were kept under check with hand weeding. Irrigation and plant protection measure were applied as per recommendation. The intercrop was harvested twice for green fodder. The harvesting of gobhi sarson was done in first fortnight of April and seed yield was recorded. Gobhi sarson equivalent yield and net returns were calculated.

The plant samples of gobhi sarson as well as intercrops from each treatment were taken to estimate N, P, K uptake at harvest. To determine total nitrogen content, a sample of 0.5 g of plant material was digested in concentrated H_2SO_4 and digestion mixture (selenium dioxide + copper sulphate + potassium sulphate). The nitrogen content (%) of plant

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material was determined by Kjeldahl's method (Piper, 1966). To determine the phosphorus and potassium content in seed and straw, sample from each treatment were grinded. The plant sample (0.5g) was digested with triple–acid mixture of HNO_3, $HCLO_3$ and H_2SO_4 in the ratio of 9:3:1. Phosphorus content was determined by using Spectronic-20 Colorimeter and potassium content was determined with Lange's Flame Photometer (Jackson, 1967).

RESULTS AND DISCUSSION

Effect on yield and yield attributes: The plant height recorded at harvest differed significantly among different intercropping systems. Maximum plant height was recorded by sole GSL 1 sown at 45 cm spacing and it was statistically at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1), GSL 1 at 60 cm + oats (1:2), GSL 1 at 75 cm + oats (1:2), GSL 1 at 90 cm + oats (1:2) and GSL 1 at 90 cm + oats (1:3) intercropping systems, but significantly higher than other intercropping systems (Table 1). Variety GSL 1 recorded higher plant height than variety GSC 6. Both gobhi sarson varieties in sole cropping gave statistically similar result of plant height as recorded in their respective intercropping systems. This may be due to their genetic makeup and interactive effect of genotypes with the environment. Dry matter accumulation is one of the most important parameter and has a marked influence on final yield realization of a crop. Sole GSL 1 sown at 45 cm row spacing recorded maximum dry matter accumulation, which was significantly higher than both GSL 1 and GSC 6 at 90 cm + oats (1:2 and 1:3) and GSC 6 at 75 cm + oats (1:2) intercropping systems, but was at par with all other intercropping systems. Variety GSL 1 at wider row spacing of 90 cm in intercropping systems recorded significantly lower dry matter accumulation as compared to sole GSL 1. Similarly, variety GSC 6 also recorded significantly lower dry matter accumulation in intercropping systems at wider row spacing of 90 cm.

Number of primary and secondary branches per plant of gobhi sarson was significantly influenced by different intercropping systems. The primary branches per plant were highest in sole crop of gobhi sarson variety GSL 1, which were statistically at par with that obtained in GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1 and 1:2), GSL 1 at 75 cm + oats (1:2) and GSL 1 at 90 cm + oats (1:2 and1:3), but significantly higher than all other intercropping systems. Variety GSC 6 also recorded statistically similar number of primary branches per plant in sole and its intercropping systems. The significant differences among different intercropping systems were due to varietal differences. Sole variety GSL 1 sown at 45 cm row spacing recorded highest number of secondary branches per plant (14.6), which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1 and 1:2), GSC 6 at 45 cm + oats (1:1), GSC 6 at 60 cm + oats (1:1 and 1:2) intercropping systems and sole cropping of GSC 6 at 45 cm, but significantly higher than all other intercropping systems. Reduction in number of secondary branches per plant of gobhi sarson under wider spacing

Table 1. Effect of intercropping systems on the growth and yield attributes of gobhi sarson

Intercropping system	Plant height (cm)	DMA* (q ha^{-1})	Primary branches $plant^{-1}$	Secondary branches $plant^{-1}$	Siliquae $plant^{-1}$	Seeds $siliqua^{-1}$	1000 seed weight (g)
T1-GSL 1 at 45 cm + oats (1:1)	179.5	91.1	6.9	14.5	270.8	23.8	3.74
T2-GSL 1 at 60 cm + oats (1:1)	175.9	88.9	6.9	14.3	267.8	23.7	3.73
T3-GSL 1 at 60 cm + oats (1:2)	175.9	87.7	6.8	13.7	261.3	23.5	3.71
T4-GSL 1 at 75 cm + oats (1:2)	175.7	85.3	6.8	12.9	257.0	23.1	3.69
T5-GSL 1 at 90 cm + oats (1:2)	173.9	82.5	6.6	12.0	238.8	22.9	3.64
T6-GSL 1 at 90 cm + oats (1:3)	173.8	82.3	6.6	11.5	237.0	22.8	3.62
T7-GSC 6 at 45 cm + oats (1:1)	141.8	86.8	5.8	13.8	252.0	23.1	3.67
T8-GSC 6 at 60 cm + oats (1:1)	141.5	85.7	5.7	13.7	248.5	22.9	3.65
T9-GSC 6 at 60 cm + oats (1:2)	138.6	84.4	5.6	13.6	244.2	22.8	3.62
T10-GSC 6 at 75 cm + oats (1:2)	136.7	81.8	5.5	12.2	238.6	22.5	3.59
T11-GSC 6 at 90 cm + oats (1:2)	136.3	79.1	5.3	11.9	229.9	22.3	3.58
T12-GSC 6 at 90 cm + oats (1:3)	135.9	78.9	5.2	11.8	228.1	22.3	3.48
T13-Sole GSL 1 at 45 cm	181.9	91.5	7.0	14.6	272.8	23.9	3.75
T14-Sole GSC 6 at 45 cm	142.2	87.0	5.8	13.9	258.3	23.2	3.68
T15-Sole oats fodder at 20 cm	-	-	-	-	-	-	-
CD (p=0.05)	10.1	7.3	1.0	1.5	26.6	NS	NS

*DMA= Dry matter accumulation

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may be due to more competition for growth resource with closer intra-row spacing. Sole cropping of variety GSC 6 at 45 cm recorded higher number of secondary branches per plant (13.9), which was significantly higher than GSC 6 at 75 cm + oats (1:2), GSC 6 at 90 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but was at par with all its other intercropping systems.

Sole cropping of GSL 1 sown at 45 cm recorded significantly higher number of siliquae per plant, which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1 and 1:2), GSL 1 at 75 cm + oats (1:2), GSC 6 at 45 cm + oats (1:1), GSC 6 at 60 cm + oats (1:1) intercropping systems and sole GSC 6 at 45 cm, but significantly higher than all other intercropping treatments. Variety GSC 6 recorded significantly higher number of siliquae per plant in sole stand as compared to GSC 6 at 90 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems. Reduction in number of siliquae per plant under wider spacing may be attributed to closer intra-row spacing. Similarly, Rana (2006) also reported that *karan rai* in intercropping system produce less number of siliquae per plant than sole crop. Number of seeds per siliqua and 1000-seed weight was not significantly influenced by different intercropping systems. Similar trend was recorded in seed and straw yield. The effect of different intercropping systems was significant on the seed yield of *gobhi sarson*. The maximum seed yield (21.01 q ha^{-1}) was obtained in sole cropping of GSL 1 at 45 cm, which was significantly higher than GSL 1 at 90 cm + oats (1:2), GSL 1 at 90 cm + oats (1:3), GSC 6 at 75 cm + oats (1:2), GSC 6 at 90 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but remained at par with all other intercropping systems. Sole oats fodder recorded significantly higher green fodder yield than under all other intercropping systems. This happened at lower plant population of oats and shading effect of gobhi sarson in the intercropping systems as compared to their pure stand. Sarkar and Mahasin (2007) also reported that pure crop of oats gave higher green fodder yield than its intercropped stand.

Effect on gobhi sarson equivalent yield and net returns: All the intercropping systems recorded significantly higher gobhi sarson equivalent yield and net returns than sole gobhi sarson (GSL 1 & GSC 6) and sole oats fodder. Sole oats fodder recorded the lowest gobhi sarson equivalent yield (19.46 q ha^{-1}). Maximum gobhi sarson equivalent yield (28.73 q ha^{-1}) was recorded with intercropping system of GSL 1 at 90 cm + oats (1:3), which was at par with GSL 1 at 60 cm + oats (1:2), GSL 1 at 75 cm + oats (1:2), GSC 6 at 60 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but significantly higher than all other intercropping systems (Table 2). Sachan and Uttam (1992) reported that mustard intercropped with gram gave higher mustard equivalent yield than sole mustard. Intercropping system of GSL 1 at 90 cm + oats (1:3) recorded

Table 2. Productivity, economics and LER of gobhi sarson and oats fodder intercropping system

Intercropping system*	*Gobhi sarson*			Oats green fodder yield (q ha^{-1})	GSEY** (q ha^{-1})	Net returns (Rs ha^{-1})	LER
	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)				
T1	20.88	79.75	20.80	130.9	26.51	54555	1.28
T2	20.54	79.34	20.55	126.2	25.97	54397	1.26
T3	20.26	78.90	20.37	195.8	28.59	57540	1.39
T4	19.08	76.85	19.80	188.7	27.20	55206	1.33
T5	18.94	75.90	19.76	160.0	25.82	52333	1.26
T6	18.93	75.88	19.76	227.7	28.73	57673	1.41
T7	19.87	77.13	20.48	148.2	26.25	53621	1.33
T8	19.70	76.79	20.28	128.0	25.21	52074	1.28
T9	19.36	76.60	20.17	206.7	28.25	56394	1.44
T10	18.13	74.11	19.68	192.9	26.43	52832	1.34
T11	17.83	72.90	19.56	191.5	26.07	52794	1.32
T12	17.77	72.82	19.53	247.3	28.41	56556	1.45
T13	21.01	81.08	20.88	-	21.01	44834	1.00
T14	19.93	77.29	20.54	-	19.93	41520	1.00
T15	-	-	-	452.2	19.46	36425	1.00
CD (p=0.05)	1.65	4.68	NS	20.2	1.69	3250	0.12

* Treatment details in Table 1 **GSEY= *Gobhi sarson* equivalent yield

Price (Rs q^{-1}): *Gobhi sarson* = 2788; Straw of *gobhi sarson* = 80; Oats fodder = 120

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maximum net returns (Rs 57673 ha^{-1}), which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:2), GSL 1 at 75 cm + oats (1:2), GSC 6 at 60 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but significantly higher than all other intercropping treatments. Singh *et al.* (1992) also reported that net return was higher in wheat + Indian mustard intercropping system than their pure crops.

Effect of land equivalent ratio (LER): Compared with sole cropping, all the intercropping systems resulted in significantly higher LER indicating the yield advantage in intercropping. Intercropping system of GSC 6 at 90 cm + oats (1:3) recorded maximum LER (1.45), which was at par with GSC 6 at 60 cm + oats (1:2), GSC 6 at 75 cm + oats (1:2), GSL 1 at 60 cm + oats (1:2) and GSL 1 at 90 cm + oats (1:3) intercropping systems, but significantly higher than all other intercropping systems.

Nitrogen, phosphorus and potassium uptake: Significant differences were observed among intercropping treatments for total nitrogen, phosphorus and potassium uptake. Maximum uptake of nitrogen (137.8 kg ha^{-1}) was observed in GSL 1 at 60 cm + oats (1:2) intercropping system, which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1), GSL 1 at 75 cm + oats (1:2), GSL 1 at 90 cm + oats (1:2 and 1:3), GSC 6 at 45 cm + oats (1:1) and GSC 6 at 60 cm + oats (1:2) intercropping systems, but significantly higher than sole and other intercropping treatments. The higher uptake of nitrogen by GSL 1 at 60 cm + oats (1:2) intercropping system may be due to higher total biomass production under this treatment. Sole oats fodder recorded significantly lower nitrogen uptake (52.8 kg ha^{-1}). Intercropping system of GSL 1 at 60 cm + oats (1:2) overlap to GSL 1 at 90 cm + oats (1:3) in total nitrogen uptake which was due to higher gobhi sarson biomass yield at 60 cm row spacing than at 90 cm row spacing. As the nitrogen content in gobhi sarson was higher than oats fodder that resulted in higher uptake by GSL 1 at 60 cm + oats (1:2).

Sole cropping and different intercropping systems recorded significant difference in phosphorus uptake. Intercropping system of GSL 1 at 60 cm + oats (1:2) recorded maximum phosphorus uptake (38.8 kg ha^{-1}), which was at par with GSL 1 at 45 cm + oats (1:1), GSL 1 at 60 cm + oats (1:1), GSL 1 at 75 cm + oats (1:2), GSL 1 at 90 cm + oats (1:3), GSC 6 at 45 cm + oats (1:1), GSC 6 at 60 cm + oats (1:1), GSC 6 at 60 cm + oats (1:2), GSC 6 at 75 cm + oats (1:2) and GSC 6 at 90 cm + oats (1:3) intercropping systems, but significantly higher than sole and other intercropping treatments.

Maximum potassium uptake (113.0 kg/ha) was recorded in GSL 1 at 90 cm + oats (1:3) intercropping system. Lower value of potassium uptake was recorded in sole crop of oats followed by sole GSC 6 and GSL 1 (Table 3). The higher uptake of potassium in intercropping systems was due to more biomass production as a result of more efficient utilization of resources by component crops. Between two varieties, GSC 6 based intercropping systems, GSC 6 at 60 cm + oats (1:2) intercropping system recorded significant highest uptake of potassium than rest of its intercropping systems except GSC 6 at 60 cm + oats (1:2) intercropping

Table 3. Effect of intercropping system on total uptake of N, P and K by plants and available N, P and K in soil

Intercropping system*	Total uptake (kg ha^{-1})			Available (kg ha^{-1})		
	Nitrogen	Phosphorus	Potassium	Nitrogen	Phosphorus	Potassium
T1	133.7	37.4	104.4	253.7	23.5	222.2
T2	130.3	35.7	102.0	244.8	23.1	217.8
T3	137.8	38.8	111.2	264.0	24.7	244.6
T4	131.8	36.3	110.8	259.9	24.3	236.3
T5	124.9	35.2	101.9	263.0	23.9	233.4
T6	133.0	36.2	113.0	265.8	26.2	263.8
T7	129.6	37.0	103.5	255.6	24.2	226.1
T8	125.7	36.1	97.5	247.2	22.8	224.0
T9	133.4	38.6	109.9	266.0	24.7	264.5
T10	126.9	35.7	103.8	263.4	24.6	247.4
T11	123.1	34.4	100.7	261.2	24.6	258.6
T12	129.1	36.4	110.7	266.2	26.0	265.1
T13	120.7	32.3	80.0	237.8	20.2	216.5
T14	114.1	30.3	76.5	241.6	22.0	224.8
T15	52.8	20.7	72.4	237.5	21.0	206.6
CD (p=0.05)	8.2	3.3	6.5	NS	NS	NS

*Treatment details in Table 1

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system.

Effect on soil status: The available nitrogen of surface soil after harvest of component crops was increased from its initial status. Intercropping systems did not significantly influence the available nitrogen status of surface soil. Available phosphorus status of surface soil did not significantly differ with different intercropping treatments. However, intercropping system of GSL 1 at 90 cm + oats (1:3) recorded higher value of available phosphorus status (26.2 kg ha^{-1}) of surface soil (Table 3). The available potassium of surface soil after harvest of crop was decreased from its initial potassium status. Effect of different intercropping systems on available potassium of surface soil was not significant. However, intercropping system GSC 6 at 90 cm + oats (1:3) recorded maximum value of available potassium (265.1 kg ha^{-1}) and lowest value (206.6 kg ha^{-1}) was recorded by sole oats fodder.

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Effect of Spacing and Nitrogen Levels on Growth, Flowering and Yield Parameters of Garden Rue (*Ruta Graveolens* L.)

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Abstract: A field investigation was carried out to study the effect of spacing and nitrogen levels on growth and yield of garden rue (*Ruta graveolens* L.). The plant height, fresh / dry herbage and root yield were significantly higher at 45 x 30 cm spacing compared to 45x45cm and 45x60cm. Improved growth parameters, flowers per plant, per cent dry matter, fresh/dry herbage and root yields were significantly higher in plants supplied with 150 kg nitrogen per hectare. Minimum days to first and fifty per cent flowering was recorded with application of 60 kg nitrogen per hectare. Plants grown at 45 x 30 cm + 150 kg N ha^{-1} combination registered maximum growth, fresh/dry herbage/ fresh root yield and per cent dry matter at harvest.

Key Words: *Ruta graveolens*, nitrogen, spacing, growth, yield

The Rutaceae family comprises of extremely wide variety of medicinal plants, mainly distributed in tropical regions. The most common medicinal plant of this family is garden rue (*Ruta graveolens* L.), which is used since times immemorial in Ethanobotany. Rue contains more than 120 natural compounds mainly including acridone alkaloids, coumarines, essential oils (0.5%), flavonoids (Rutin), and furoquinolines (1.4%) found in the roots and aerial parts of this plant and is the main source of furanocoumarins such as psoralen, xanthotoxin (8-meth- 8710 oxypsoralen; 8-MOP) and bergapten (5-methoxypsoralen; 5-MOP), which are valued in pharmaceutical industry. The compound responsible for the bitter taste is Rutin (7 to 8% in the dried leaves).

It has been used as an antispasmodic, as a treatment for menstrual problems, as an abortifacient, and as a sedative. The whole herb is anthelmintic, antidote, carminative, emetic, emmenagogue, expectorant, haemostatic, ophthalmic, rubefacient, strongly stimulant, mildly stomachic and uterotonic. Ruta in combination with calcium phosphate [$Ca_3(PO4)_2$] could be used as effective treatment for brain cancers, particularly glioma (Pathak *et al.*, 2003). Spacing and nutrients are important factor, which can limit crop growth and yield. It is possible to produce higher yields by judicious practices in the supply of nutrients and adoption of proper spacing. Being an herbaceous crop, great potential exists for increasing the plant growth and yield through the application of inorganic nitrogenous fertilizer. In this context, the study was conducted to evaluate the effect of spacing and nitrogen levels on growth, flowering and yield parameters of garden rue (*Ruta graveolens* L.).

MATERIALS AND METHODS

Field experiment was conducted at the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, Gokak Taluk, Belgaum district of Karnataka state from September 2012 to February 2013. This experiment was laid out in Factorial Randomized Block Design (FRBD) with twelve treatments and three replications. The treatments consisted of two factors viz., spacing with three levels (45 x 30 cm, 45 x 45 cm and 45 x 60 cm) and nitrogen fertilizer with four levels (60, 90, 120 and 150 kg ha^{-1}). The size of the experimental plot was 3.0 m x 1.8 m with different spacing levels. Well decomposed FYM was applied 15 days before transplanting, at the rate of 10 ton per hectare and mixed thoroughly into the soil. The treatments were allocated to individual plots at random. Spacing was adopted in each plot as per the treatment allocation. The nutrients were applied in the form of straight fertilizers with nitrogen in the form of urea, phosphorous in the form of single super phosphate and potassium in the form of muriate of potash. The seedlings were raised from seeds in two nursery beds of 15 cm height, 1 m width and 2.5 m length. Fifty days old, healthy and uniform sized seedlings were selected and transplanted in the experimental plots as per the treatments.

The fertilizer mixture was applied by broadcasting uniformly in rows to individual plots as per the treatment and mixed thoroughly in to the soil. Out of total quantity, half dose of nitrogen and full dose of phosphorous (30 kg ha^{-1}) and potash (30 kg ha^{-1}) were supplied as basal dose one day before transplanting. The remaining half quantity of nitrogen was given as top dressing at 45 days after

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transplanting. The first irrigation was given immediately after transplanting and irrigated once in a week or fifteen days during the whole cropping period. The crop was harvested five months after transplanting at full flowering stage asit contains maximum percentage of active principles at this stage. Harvested herb was cut into pieces of convenient length along with flowers and immature capsules. This material was dried under partial shade for few hours and used for essential oil extraction. Observations were recorded on plant height, number of primary branches, plant spread, stem girth at harvest stage i.e., 150 days after planting (DAP). Flowering parameters like number of flowers and days to first and fifty per cent flowering were also recorded at flowering stage. Yield characters like per cent dry matter, fresh and dry herbage and fresh root yield per plant, plot and hectare were recorded during harvesting.

RESULTS AND DISCUSSION

Effect of spacing levels: A perusal of data in table 1 indicates that the wider spacing of 45 x 60 cm caused significant promotion in number of primary branches per plant (11.64), plant spread {E-W (48.91 cm) and N-S (45.76 cm)} and stem girth (12.96 mm) 150 DAP compared with other levels of spacing. The increase in various growth characters may be attributed to the availability of more spatial area for spreading, which helped in more interception of light due to higher surface area, which produced better growth. Meanwhile, the significant increment of plant height was recorded at narrow spacing (45 x 30 cm). The increased plant height in closer spacing might be due to competition among plants for solar energy (light). The plant height increases with an increase in plant density has also been reported by Gangadharappa (1987) in *Ammi majus* and Subbireddy *et al.* (1991) in *Solanum viarum*.

Flowering in garden rue was significantly influenced by spacing levels except days to 50 per cent flowering (Table 1). Earliest flowering was observed in plants spaced at 45 x 45 cm (S_2). While delayed flowering was observed in treatment 45 x 60 cm (S_3). This may be attributed to the

Table 1. Effect of spacing and nitrogen levels on growth and flowering characters of garden rue (*Ruta graveolens* L.)

Treatments	Growth parameters					Flowering parameters		
	Plant helght (cm)	No. of primary branches	Plant spread {E-W (cm)}	Plant spread {N-S (cm)}	Stem girth (mm)	Days to first flowering	Days to fifty per cent flowering	Number of flowers per plant
Spacing level (S)								
S_1 : 45x30 cm	45.42	10.31	46.09	43.15	11.62	122.42	141.08	536.92
S_2 : 45x45 cm	43.48	10.74	47.01	44.80	12.07	120.00	140.08	545.83
S_3 : 45x60 cm	42.57	11.64	48.91	45.76	12.96	126.67	143.58	552.92
CD (0.05)	1.87	0.83	2.13	1.93	0.66	4.37	NS	7.57
Nitrogen level (N)								
N_1 : 60 kg N ha^{-1}	41.08	9.82	43.02	41.94	11.18	114.22	133.44	520.33
N_2 : 90 kg N ha^{-1}	41.88	10.50	45.25	42.42	11.67	123.44	141.78	541.78
N_3 : 120 kg N ha^{-1}	44.98	11.12	47.97	45.83	12.30	124.11	144.00	546.56
N_4 : 150 kg N ha^{-1}	47.35	12.14	53.11	48.10	13.71	130.33	147.11	572.22
CD (0.05)	2.16	0.96	2.46	2.23	0.77	5.04	6.98	8.75
Interaction (S x N)								
S_1N_1	43.33	9.47	41.74	40.44	10.75	112.33	129.33	511.67
S_1N_2	40.76	9.97	44.78	40.88	10.86	120.00	142.00	530.00
S_1N_3	47.11	10.03	48.01	44.22	11.50	127.67	144.33	538.33
S_1N_4	50.50	11.77	49.85	47.07	13.37	129.67	148.67	567.67
S_2N_1	38.93	9.12	42.00	41.91	11.10	111.33	133.00	522.67
S_2N_2	41.96	10.80	44.93	43.3	11.66	121.67	143.67	544.67
S_2N_3	44.65	11.20	47.37	45.79	12.37	116.33	143.00	542.67
S_2N_4	48.36	11.83	53.74	48.19	13.14	130.67	140.67	573.33
S_3N_1	40.98	10.87	45.33	43.47	11.69	119.00	138.00	526.67
S_3N_2	42.92	10.73	46.03	43.07	12.49	128.67	139.67	550.67
S_3N_3	43.17	12.13	48.52	47.47	13.04	128.33	144.67	558.67
S_3N_4	43.20	12.83	55.75	49.04	14.64	130.67	152.00	575.67
CD (0.05)	3.74	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.05	9.09	5.33	5.13	6.46	5.19	5.04	5.64

NS: Non-significant

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Table 2. Effect of spacing and nitrogen levels on yield parameters of garden rue (*Ruta graveolens* L.) at harvesting stage

Treatments	Fresh herbage yield hectare^{-1} (ton)	Dry herbage yield hectare^{-1} (ton)	Fresh root yield hectare^{-1} (ton)	Per cent dry matter
Spacing level (S)				
S_1 : 45x30 cm	16.00	3.63	2.06	21.49
S_2 : 45x45 cm	14.06	3.31	1.85	22.75
S_3 : 45x60 cm	12.53	2.72	1.76	23.85
CD (0.05)	0.80	0.21	0.16	0.97
Nitrogen level (N)				
N_1 : 60 kg N ha^{-1}	13.16	2.99	1.77	21.55
N_2 : 90 kg N ha^{-1}	13.57	3.17	1.83	21.91
N_3 : 120 kg N ha^{-1}	14.51	3.22	1.88	22.69
N_4 : 150 kg N ha^{-1}	15.54	3.49	2.09	24.64
CD (0.05)	0.92	0.24	0.19	1.12
Interaction (S x N)				
S_1N_1	14.52	3.43	1.83	20.43
S_1N_2	14.77	3.46	1.95	20.08
S_1N_3	17.31	3.45	2.13	20.72
S_1N_4	17.40	4.16	2.34	24.72
S_2N_1	13.74	3.01	1.87	22.03
S_2N_2	14.62	3.58	1.77	21.11
S_2N_3	15.25	3.53	1.97	23.33
S_2N_4	12.62	2.55	1.80	24.53
S_3N_1	11.22	2.52	1.61	22.18
S_3N_2	11.31	2.47	1.77	24.52
S_3N_3	10.98	2.12	1.53	24.02
S_3N_4	16.59	3.77	2.13	24.68
CD (0.05)	1.61	0.43	0.33	1.94
CV (%)	6.70	7.92	10.58	5.04

competition among plants for nutrients, water and sunlight thus forcing the plants to turn to reproductive phase early as reported by Marutiprasad (2002) in davana. Maximum number of flowers per plant (552.92) was registered at 45 x 60 cm and minimum (536.92) at 45 x 30 cm. This might be due to more number of branches, more plant spread, which produced more flowering branches by the utilization of more space by the plants for production of flowers at this spacing.

At harvest, significantly higher fresh and dry herbage (16.00t and 3.63t, respectively) and fresh root yield per hectare (2.06 t) was noticed in closer spacing (45 x 30 cm). This might be due to the luxuriant growth of plants during vegetative phase and accommodation of more number of plants per unit area due to closer spacing helped to accumulate higher dry matter resulting in higher herbage and root yields. Whereas, wider spacing of 45 x 60 cm recorded more per cent dry matter (Table 2). This might be due to the fact that widely spaced plants put up better vegetative growth and accumulated more dry matter content through better utilization of light, moisture and space resulting in higher per cent dry matter.

Effect of nitrogen levels: The application of nitrogen at different levels improved most of growth characters significantly at 150 DAP (Table 1).Generally, higher level of nitrogen (150 kg ha^{-1}) recorded significantly higher plant height (47.35 cm), more number of primary branches per plant (12.14), plant spread {E-W (53.11 cm) and N-S (48.10 cm)} and stem girth(13.71 mm) compared to other treatments. The least growth was noticed at lower nitrogen level of 60 kg ha^{-1}. The positive influence of nitrogen on plant height might be due to the fact that nitrogen is required for cell division and cell elongation, which triggers the growth of meristamatic tissue and the efficient utilization of this by the plants might manifested in production of taller plants with more number of branches, plants spread and stem girth. These results are in agreement with the findings of Kumar *et al.* (2006) and Malik *et al.* (2012) in garden rue.

Flowering was significantly influenced by nitrogen aoolication (Table 1). The least number of days to first (114.22) and 50 per cent flowering (133.44) was observed

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in plants supplied with 60 kg N ha^{-1}, while the maximum number of days to first and 50 per cent flowering was recorded with 150 kg N ha^{-1}. This may be attributed to the positive role of nitrogen on vegetative growth which delayed the flowering. The identical results have been reported by Kavitha and Vadivel (2006) in *Mucuna pruriens*. More number of flowers per plant, higher fresh/dry herbage and fresh root yield was registered in plants supplied with the higher nitrogen level (150 kg N ha^{-1}) and minimum was noticed in plants supplied with 60 kg N ha^{-1} (Table 2). This could be attributed to the enhanced availability of nitrogen at the appropriate time, which might have resulted in increased photosynthetic rate and accumulation of metabolites in plants.

Effect of interaction between spacing level and nitrogen fertilization: The plants grown at spacing of 45 x 30 cm and supplied with 150 kg of N ha^{-1} registered significant increase in plant height (50.5 cm) at 150 DAP (Table 1).This may be due to positive effect of spacing and nitrogen individually on plant height and the same beneficial effect has been reflected in the combination also.

Significant differences were found among yield parameters due to interaction (Table 2). The combination of highest level of nitrogen and narrow spacing must have given the plants more scope to put better growth by producing increased plant height, branches, plant spread and accommodation of more number of plants per unit area resulting in higher herbage and root yields and per cent dry matter. The results are in line with the findings of Sherbeny *et al.* (2007) in garden rue.

It may be concluded that, among different spacing levels planting of garden rue at 45 x 30 cm spacing is beneficial for obtaining the maximum plant height, herbage and root yields. Among nitrogen levels, application of 150 kg nitrogen per hectare is favorable for getting improved growth characters, flowers per plant, higher herbage and root yields and per cent dry matter. Growing of garden rue at 45 x 30 cm spacing and supplemented the crop with 150 kg nitrogen per hectare is valuable for obtaining the highest herbage and root yields and per cent dry matter under northern dry zone of Karnataka.

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Performance of Cabbage Hybrids for Various Horticultural Traits in the Plains of Punjab

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Abstract: An experiment was conducted to assess the performance of eight cabbage hybrids from private source during winter season of 2010-11 and 2011-12. The ANOVA revealed that there existed significant differences among the hybrids for all the characters when analyzed for individual years and also when pooled over the years. The MS due to years were significant for all the characters except head length, number of outer leaves and stalk length indicating that the hybrids responded differently to the changing environmental conditions. The interaction between years x hybrids was significant for all the characters. Hybrid KTCBH-81 took minimum days (83.67) to reach maturity. Plant spread (49.18cm), stalk length (10.20cm), head width (16.13cm) and net weight of head (789.50g) was maximum in hybrid BC-76. Similarly head length (21.25cm) and net yield (288.75q ha^{-1}) was maximum with KTCBH-81. Therefore, hybrid KTCBH-81 and Bc-76 are most suitable for cultivation under Punjab conditions.

Key Words: Cabbage, hybrids, performance, head weight

INTRODUCTION

Cabbage is the second most important crop of the cole group grown under temperate to tropical climate conditions for its head in more than ninety countries throughout the world (Singh *et al.*, 2010) and the leading countries are China, India, Russia, Korea, Japan and the USA. In India, it is cultivated in 389.62 thousand ha area with a production statistics of 8412.12 metric tones ha^{-1}. It is also rich source of ascorbic acid, carotene (pro. Vitamin A) and has high fiber content and calcium which reduces the risk of colon cancer (Swarup, 2006). It is a rich source of protein comprising all essential amino acids, especially sulphur containing amino acids, minerals such as calcium, iron, magnesium, sodium, potassium, phosphorus and antioxidant and is reported to have anti-carcinogenic properties (Singh *et al.*, 2009). Cabbage is cultivated for its head which is consumed as salad and cooked as well and its outer leaves are also used as animal fodder. Selective breeding has produced several distinct types of cabbage: early, midseason and late; green and purple; large and small heads; flat, oval, conical and globular; savoy types; and those with either smooth or crumpled leaves (Singh *et al.*, 2006).

Cabbage is a cool season crop and requires 18-25°C for germination of seed, 7-25°C for vegetative growth and 18-25°C for head formation (Dhaliwal, 2012). This range of temperature for cabbage production is available during winter months in Punjab. However, seed production in tropics and sub tropics is not feasible because of insufficient chilling to promote flowering. Cabbage needs temperature in the range of 4.4 to 10°C for 60 days for flowering, which is not feasible under subtropical conditions of India (Fang *et al.*, 2004). Therefore cabbage breeding and seed production takes place outside India. Seed is imported from Europe and is sold by seed companies and other retail outlets. Most of these hybrids/varieties are described to be high yielding and with varying levels of resistance to diseases. Important horticultural characters in cabbage are head size, shape and firmness, taste, maturity. Evaluating cabbage hybrids for adaptation and yield will help farmers, breeders and seed companies select and develop hybrids/varieties best suited to the local environment and market. Therefore the present investigation was carried out to evaluate the commercial hybrids acceptable for fresh market.

MATERIAL AND METHODS

The present investigation was conducted at the Vegetable Research Farm of the Punjab Agricultural University (PAU), Ludhiana during the crop seasons 2010-11 and 2011-12. The experimental materials comprised of 7 cabbage hybrids from different public sectors and private companies (Table1). Sowing in nursery beds was done in the last week of September and seedlings were transplanted in the field in the last week of October during both the years of testing. Each hybrid was planted in a plot having 3.6 × 2.4 m area in randomized block design with three replications. There were 30 plants in each plot planted at row and plant spacing of 60 × 45 cm. All the standard package of practices and plant protection measures were timely adopted to raise the crop successfully. Duration of crop, duration of 50% head maturity were recorded from the entire plot of each replication while ten plants were selected randomly from each replication for recording observations viz., plant spread

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(cm), head length (cm), head width (cm), net weight of head (g), number of outer leaves, stalk length (cm) and net yield (q ha^{-1}). The data recorded for the individual years and pooled mean values were used for estimating the analysis of variance as suggested by Panse and Sukhatme (1978).

Table 1. Hybrids of cabbage from public and private source

Sr No	Name of hybrid	Source
1.	KTCBH-51	IARI(Katrain)
2.	KTCBH-81	IARI(Katrain)
3.	BC-64	Syngenta
4.	BC-76	Syngenta
5.	Godavari	Clause
6.	Nilgiri	Clause
7.	Quisto (C)	Syngenta

RESULTS AND DISCUSSION

The results pertaining to the analysis of variance for the experimental design are reported in Table 2. The Anova revealed that there existed significant differences among the hybrids for all the characters when analysed for individual years and also when pooled over the years. The MS due to years were significant for all characters except head length, number of outer leaves and stalk length. This suggested that the duration of crop, plant spread, head width, net head weight, yield were more influenced by the change in environment. The mean sum of square due to interaction between years x hybrids were significant for all the characters studied indicating that the hybrids responded differently to the changing environmental conditions. The relative performance (mean over years) of different cabbage hybrids for various economic characters is in individual years and their mean values are reported in Table 3 and Table 4. Cabbage entries also differed significantly in their life cycle expressed in number of days to harvest time in both the years indicating the effect of environment. In the first year of evaluation, the numbers of days to harvest were more than second year. This may be due to favourable temperature during growth of crop in second year. The minimum number of days to curd formation were found in hybrid KTCBH-81 (83.67) followed by hybrid Godavari (85.83). The variation in duration of crop among different hybrids may be due to their specific genetic make up, inherent properties and environmental factors. Meena *et al.* (2012) reported the range of 71.28 to 110.53 days to maturity in 30 cabbage genotypes. Similar results were reported by Obiadalla *et al* (2012) and Greenland *et al.* (2000). Plant spread is a desirable character in cabbage because the growth and head size depends upon the spread of the plant. It should be medium in size. Maximum mean value of plant spread was reported in hybrid BC-76 (49.18 cm) followed by hybrid BC-64 (45.28 cm). Minimum plant spread was recorded in hybrid KTCBH-51. The variation in plant spread among different hybrids is due to their different genetic make up. Number of outer leaves is an important trait and it should be restricted to minimum as excess vegetative growth reduces the head weight especially in early maturing hybrids. When a cabbage plant grows, it first increases the number of wrapper leaves and extends the area of each leaf. Second, it starts to express head formation in the middle of developmental stage and finally forms mature head with adequate size by increasing the number and weight of the head leaves during continous vegetative growth Tanaka and Nikiiura (2003). All the hybrids showed variation in respect to number of outer leaves. Minimum number of leaves were reported in hybrid BC-64 (12.67) followed by KTCBH-81 (14.50) and maximum were in Hybrid Quisto. Significant differences were found among cabbage entries in both seasons for stalk length. Hybrid BC-76 had maximum stalk length (10.20 cm) followed by hybrid BC-64 (9.75cm) and these were significantly better than other hybrids.

Table 2. Analysis of variance for various growth and yield characters in cabbage over years

Year	Source of Variation	Degree of freedom	Mean squares							
			Duration of crop	Plant spread (cm)	Head length (cm)	Head width (cm)	Net weight of head (g)	Net yield (q/ha)	Number of outer leaves	Stalk length (cm)
2010-11	Hybrids	6	86.83*	67.79*	19.52*	3.38*	19703.87*	3095.27*	21.43*	41.42*
	Error	12	0.57	1.34	0.17	0.20	215.07	49.14	1.48	0.32
2011-12	Hybrids	6	81.42*	42.63*	14.00*	3.57*	19769.33*	2961.84*	22.43*	6.98
	Error	12	2.31	1.25	0.24	0.17	182.23	77.40	0.95	4.13
Pooled	Environments	1	1748.59*	11.31*	0.005	6.10*	5348.00*	614.25*	1.17	1.80
	Hybrids	6	92.80*	98.50*	32.06*	7.05*	40194.45*	6212.80*	42.52*	18.54*
	Interaction	6	77.92*	18.92*	1.08*	0.29*	960.22*	23.01*	1.33*	1.88*
	Error	24	1.39	1.29	0.21	0.19	205.10	63.88	1.21	2.23

* Significant at $P \leq 0.05$

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Table 3. Relative performance of identified cabbage hybrids for various growth and yield characters for two years

Hybrids	Duration of crop			Plant spread (cm)			Number of outer leaves			Stalk length (cm)		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
KTCBH-51	100.33	77.33	88.83	34.83	37.00	35.92	16.33	17.00	16.67	6.37	6.53	6.45
KTCBH-81	91.00	76.33	83.67	45.33	41.67	43.50	14.00	15.00	14.50	5.73	5.57	5.65
BC-64	101.67	83.33	92.50	45.57	45.00	45.28	12.33	13.00	12.67	9.83	9.67	9.75
BC-76	98.67	81.67	90.17	50.36	48.00	49.18	20.00	19.33	19.67	10.67	9.73	10.20
Godavari	89.67	82.00	85.83	40.50	42.00	41.25	15.33	14.33	14.83	5.63	5.86	5.75
Nilgiri	88.67	85.00	86.83	40.47	44.00	42.23	16.33	16.33	16.33	5.70	5.70	5.70
Quisto (C)	98.00	92.00	95.00	40.67	47.33	44.00	19.00	20.67	19.83	8.07	8.03	8.05
CD at 5%	1.22	2.70	1.69	2.06	1.99	1.45	2.16	1.73	1.31	1.01	0.90	1.78

Table 4. Relative performance of identified cabbage hybrids for various growth and yield characters for two years

Hybrids	Head length (cm)			Head width (cm)			Net weight of head (g)			Net yield (q ha^{-1})		
	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled	2010-11	2011-12	Pooled
KTCBH-51	15.17	15.17	15.17	12.50	13.57	13.03	662.33	670.00	666.17	245.33	249.65	247.49
KTCBH-81	21.50	21.00	21.25	15.40	15.77	15.58	763.33	765.00	764.17	284.67	292.82	288.75
BC-64	19.20	19.40	19.30	15.60	16.67	16.13	608.33	626.67	617.50	226.00	230.32	228.16
BC-76	18.27	16.83	17.55	14.13	15.33	14.73	757.67	821.33	789.50	282.00	290.05	286.02
Godavari	16.57	17.00	16.78	14.70	15.40	15.05	688.33	698.33	693.33	254.33	259.76	257.05
Nilgiri	16.03	15.87	15.95	14.17	14.17	14.17	723.33	726.67	725.00	265.00	272.60	268.80
Quisto (C)	14.23	15.57	14.90	13.20	14.13	13.67	530.00	583.33	556.67	191.00	206.67	198.84
CD at 5%	0.76	0.87	0.49	0.82	0.72	0.58	26.87	24.02	22.17	12.63	15.66	13.75

Minimum stalk length was observed in KTCBH-81 (5.65cm). Meena *et al.* (2012) and Obiadalla *et al.* (2012) reported variation in the stalk length of the cabbage hybrids. Head length is an important character that represents the shape of the head and appeals to the consumer. Data presented in Table 4 revealed that head length was not influenced by environments and maximum was observed in KTCBH-81 (21.25 cm) and is significantly better than all the hybrids. The minimum mean value of head length (15.17 cm) was found in hybrid KTCBH-51. Similarly head width was maximum in BC-64 (16.13 cm) followed by KTCBH-81 (15.58 cm) and these hybrids were significantly better than other hybrids. Greenland *et al.* (2000) reported the range of head length and width of 12.75 to 19.50 and 12-18 cm, respectively, while Meena *et al.* (2012) reported the range 12.10 to 31 cm and 12.43 to 27.40 cm for head length and width, respectively. Similar results were reported by Adeniji *et al.* (2010) and Janko *et al.* (2011).

Data presented in Tables 4 revealed significant differences among cabbage hybrids for net weight of head. Net weight of cabbage hybrid was more in second year than first year that may be due to early winter that caused favourable growth of the crop. Similarly net head weight is directly correlated with the head length and width (Janko *et al.* 2011). Maximum mean value of net weight of head (789.50g) was observed in hybrid BC-76, which is statistically better than all the hybrids. Cabbage hybrid Quisto gave lowest mean value (556.67g) of net weight of head. Data presented in Table 4 revealed significant differences among different hybrids of cabbage for net yield. Net yield in second year was higher than the first year which may be due to early winter in second year that resulted in better growth and weight of the head and increased the yield. The maximum mean value for net yield was observed in hybrid KTCBH-81 (288.75q ha^{-1}) followed by hybrid BC-76 (286.02 q ha^{-1}) and both were statistically at par with each other but better than other hybrids. Quisto recorded the minimum yield (198.84 q ha^{-1}). Meena *et al.* (2012) reported the variation in cabbage hybrid yield ranging from 111-566q ha^{-1}. Similar findings were reported by Obiadalla *et al.* (2012), Greenland *et al.* (2000), Adeniji *et al.* (2010). Based upon the field performance, the hybrid KTCBH-81 and hybrid BC-76 were found suitable for fresh fruit market.

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Influence of Sowing Dates on Phenotypic Traits in Sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract: The experimental material consisted of 35 elite sorghum genotype including hybrid parents (restorer and maintainer) hybrids and varieties. The experimental material was evaluated over six different dates of sowing ranging from 20th September to 27th October. The influence of dates of sowing on different phenotypic characters indicated that delayed sowing reduced the expression of all the traits. Flowering was early when genotypes were sown at 5th October. The grain yield in general was high in the genotype sown at 20-28th September compared to the remaining dates. The seed set percentage (irrespective of sowing dates) was more than 65 per cent as long as minimum temperature was more than 13ºC, whereas, it was drastically reduced when minimum temperature was dropped down below 10ºC. Mean performance of genotypes for the seed set percentage, test weight, grain number per panicle was lowest in the B lines compared to R lines. This suggests that there is need to improve the existing B lines for these traits. The genotypes AKMS14B, 101B, 296B, 116B and BJMS2B showed narrow range of mean grain yield per plant compared to the highest range recorded by CSH-19R across sowing dates and temperature regimes. These results revealed that the above genotypes could be used further for the development of new breeding lines, which are less sensitive to sowing dates and temperature regimes in *rabi* season.

Key Words: Temperature sensitivity, *rabi* sorghum, genotypes pollen fertility, seed setting, temperature regimes

Among major cereals in the world, sorghum ranks fourth after wheat, rice and maize in area. In India, it ranks third after wheat and rice. It is hardy and dependable crop that grows well under adverse conditions and can thus play a major role in increasing food production in the semi-arid tropics. The *Rabi* sorghum is cultivated using the conserved moisture in black soils and sowing is generally done at favorable moisture conditions that occur after the first week of September. The sowing dates vary from location to location and year to year, and usually extend up to the end of October. Minimum temperature declines from about 20˚C at sowing to 12˚C at flowering and increases to 18˚C during grain filling period. The post-rainy season adapted land races are photoperiod sensitive, thermo insensitive, tolerance to moisture stress and produce high biomass and possess bold and lustrous grains, however the productivity of these land races are low (Sanjari *et al.*,1994; Veerabadhiran *et al.*, 2001). The present experiment was planned and conducted to understand the effect of environmental factor on different phenotypic trait and to identify suitable/ promising genotypes.

MATERIALS AND METHODS

The present investigation was carried out during *rabi* season at Regional Agriculture Research Station, Bijapur. The experimental material consisted of 35 elite sorghum genotypes including hybrid parents (restorers and maintainers), hybrids and varieties. The experimental material was evaluated over six different dates of sowing. Each sowing was taken with an interval of 7-8 days, so as to adjust flowering at different temperature regimes. The details of sowing were September 20,28, October,5,12,19 and 27. The experiment was laid out in a randomized complete block design (RCBD) with two replications in all test environments. The genotypes were allotted randomly within each replication. Each genotype was of two rows of four meter length. The inter and intra-row spacing of 60 cm and 15 cm was provided respectively. Sowing on first four dates was carried out under rainfed situation and for last two dates irrigation was provided at the time of sowing as the *in situ* soil moisture was insufficient for germination. In each replication and in each genotype, five plants were randomly selected for recording observations on twelve quantitative characters *viz.*, plant height (cm), days to 50% flowering, number of leaves per plant, length of the panicle (cm), panicle weight (g plant^{-1}), panicle diameter (cm), primary branches per panicle, grains per panicle, 500grain weight, grain yield per plant, seed setting percentage and pollen fertility percentage were considered for statistical analysis and data were analyzed using SPAR 1 software

RESULTS AND DISCUSSION

The comparison of means for plant height over six dates indicated that at 5th October sowing, plant height was not affected as compared to delayed sowing at 27th October but produced more number of leaves. When onset of cold temperature coincides with flowering, thus pollen fertility percentage was got affected. In this situation, delayed

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sowing to avoid cold injury helps in increased pollen fertility but seed set percentage was low in genotypes with delayed sowing indicating that seed setting is not solely dependent on pollen fertility (Chuan Gen- Lu *et al.*, 2002, Powar *et al.*, 2003). Delayed sowing negatively affected the performance of the genotype by reducing number of seeds per panicle and ultimately the yield (Chikurte *et al.*,2003, Tiwari *et al.*, 2003). The yield was not so affected when sowing was done early i.e. 20th September, 28th September and 5th October by virtue of high seed setting indicating that this period is optimum for sowing to get highest productivity (Table 1).

Mean performance of genotypes across dates of sowing : The genotype, CSV-216R (78.33) required more number of days to 50% flowering followed by BRJ-358, DSV-5 and DSV-4, while DSH-3 was earliest in flowering followed by CSH16, CSH 15R , CSH 19R , 401B and across six dates (Table 2). Mean value over environments indicated that CSV-216R had highest panicle weight (78.33 g) followed by CSH19R and 101B had lowest panicle weight. With respect to panicle weight, CSV-216R had highest panicle weight (63.52 g) followed by M31-2B and BRJH 129. Pollen fertility is not affected much in genotype BRJ-358 , CSV216R, SPV-570 and M35-1 but drastic reduction in pollen fertility was observed in ICSB-37 , CSH-14 and 401B . Mean value of six dates indicated that CSH19R had maximum number of seeds per panicle (1921.24) followed by BRJ 358 and CSV126R. Performance across the dates indicated that, the genotype CSH 19R (65.51g plant^{-1}) was high yielder followed by CSV 216R and BRJ-358. These genotypes can be sown in wide range of sowing time starting from second fortnight of September to last week of October.

Comparative mean performance of maintainers (B lines), restorers (R lines), stay-green lines, hybrids and varieties for different characters: The average performance of B lines, R lines, varieties, hybrids and stay-green lines, as these groups are distinct in their origin and pedigree were compared to know their behavior across the dates of sowing and temperature regimes (Table 3). The results revealed that the average plant height of B lines was lowest (131.6 cm) followed by R lines, hybrids and the varieties. With respect to days to 50 per cent flowering, hybrids were earliest to flower (69.6 days) followed by B lines, R lines and varieties. The two traits plant height and days to flowering are considered important for successful hybrid seed production and the present material (B and R lines) appeared to be suitable and useful from this point of view. However, mean performance of genotypes for the seed set percentage, test weight, grain number per panicle was lowest in the B lines compared to R lines and other categories. This suggests that there is need to improve the existing B lines for these traits. The two stay-green lines *viz.*, B35 (temperate type) and RSG03123 (derivative of temperate tropical cross) recorded lowest mean performance for all the characters indicating their unsuitability to *rabi* season. This indicates that, while introducing stay-green trait into R16 (tropical) from B35, as well as B lines derived from tropical temperate crosses the temperature sensitivity is introduced in tropical sorghum, the otherwise tolerant to temperature variations. The varieties which are tropical in origin are less sensitive to change in temperature regimes. Reddy *et al.* (2003) opined that the improved cultivars derived using temperate sorghums were found to be photoperiod insensitive and temperature sensitive. Because of this temperature sensitivity their growth is reduced and development is delayed in *rabi* season. Therefore, improved *rabi* season cultivars (which involves temperate blood) usually to fail to perform well in *rabi* season.

The genotype showing less range of variation across the dates of sowing and temperature regimes will be advantageous from the point of view of developing or identifying the genotypes for advanced or late sown situation (Reddy *et al.*,1987). Keeping this in view, comparison was made for four important traits *viz.*, plant height, days to 50% flowering, seed set percentage and grain yield per plant (Table 4). The minimum variation in height between dates was recorded by the genotypes 116B, B35, 104B and DSH3 and highest variation by BRJH-129 suggesting that these can be used for developing genotypes with optimum plant

Table 1. Pollen fertility and seed set percentage across different dates of sowing

Date of sowing	Pollen fertility percentage		Seed set percentage	
	Mean	Range	Mean	Range
20th September	91.18	58.6-97.5	65.40	36.5-86.0
28th September	93.87	85.5-98.9	74.12	31.4-92.8
5th October	92.70	72.6-98.4	70.94	24.9-95.1
12th October	93.05	81.2-97.9	73.77	6.4-95.5
19th October	94.41	79.5-99.0	64.85	9.1-90.8
27th October	95.35	82.6-99.7	57.79	17.0-79.0

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Table 2. *Mean and range for different parameters among different genotypes across dates of sowing*

Genotypes	*PH*	*NLS*	*50%F*	*PW*	*PL*	*PD*	*NP*	*PF(%)*	*SS(%)*	*TW*	*NS*	*YPP*
401B	119.32	6.08	70.92	47.47	22.73	12.69	47.15	90.82	65.71	14.94	1370.12	40.64
	(94.4 -130.50)	(5.30-7.15)	(64.0-76.50)	(24.60-72.30)	(19.20-25.10)	(10.60-14.30)	(33.10-55.50)	(86.29-94.92)	(48.70-66.72)	(14.05-15.95)	(576.57-2122.16)	(17.65-59.65)
104B	134.75	6.35	73.33	55.00	21.52	13.12	53.55	92.70	65.35	14.63	1478.08	42.48
	(117.50-150.0)	(5.30-7.30)	(64.50-80.50)	(30.40-68.30)	(18.10-23.60)	(11.60-14.20)	(45.70-61.40)	(85.58-97.62)	(53.75-78.23)	(13.25-15.90)	(606.11-2209.34)	(19.15-63.20)
296B	129.08	6.16	74.17	40.78	23.10	12.60	49.59	88.46	57.70	13.66	1104.10	29.31
	(107.50-39.50)	(5.15-7.75)	(73.00-77.00)	(34.20-53.80)	(17.90-28.0)	(11.90-13.70)	(38.80-59.30)	(58.69-95.80)	(48.59-81.85)	(11.40-16.45)	(894.15-1629.640	(23.80-37.30)
AKMS 14B	107.53	6.19	73.83	33.59	22.20	11.65	44.89	96.21	52.92	11.18	1182.34	24.50
	(69.35-123.0)	(5.45-7.15)	(69.00-83.50)	(18.30-41.80)	(18.40-24.90)	(9.70-13.10)	(35.70-48.70)	(85.25-99.0)	(24.92-69.77)	(8.45-13.30)	(782.79-1499.05)	(18.50-31.40)
1409B	114.96	5.86	71.08	47.66	26.38	11.81	46.25	90.80	64.33	12.17	1217.41	29.32
	(83.65-134.0)	(5.15-6.80)	(65.00-77.00)	(21.30-68.25)	(18.40-31.20)	(9.80-14.70)	(35.50-52.80)	(81.23-98.15)	(52.07-76.45)	(11.10-12.90)	(730.83-1854.39)	(15.90-41.35)
116B	119.21	6.53	75.50	51.12	21.10	13.88	51.42	94.32	82.61	13.50	1295.55	33.70
	(108.5-134.5)	(5.50-8.45)	(68.50-84.00)	(27.10-63.40)	(14.60-24.40)	(11.00-15.35)	(31.90-59.30)	(91.17-95.65)	(77.25-94.70)	(10.35-15.60)	(644.45-1676.12)	(20.00-38.10)
M31-2B	176.92	7.62	75.00	57.64	16.36	14.43	60.39	96.00	77.95	14.99	1569.86	46.53
	(137.5-202.0)	(6.80-8.80)	(71.00-83.50)	(35.20-74.10)	(13.90-18.60)	(12.20-17.00)	(48.60-62.50)	(93.29-98.46)	(61.95-91.36)	(12.70-15.95)	(746.07-2041.19)	(23.75-61.45)
BJMS-1B	158.08	6.48	71.17	49.41	23.85	12.95	53.67	92.98	77.56	12.92	1252.70	33.47
	(112.0-188.5)	(4.80-7.65)	(65.00-81.00)	(17.80-72.20)	(17.80-26.80)	(8.50-15.50)	(37.00-60.80)	(87.50-96.46)	(65.50-95.57)	(9.25-16.65)	(323.95-1878.85)	(7.20-45.65)
BJMS-2B	152.67	6.42	70.33	52.83	23.77	13.28	56.77	93.57	75.60	14.43	1209.54	34.68
	(119.5-179.5)	(5.95-7.65)	(66.00-77.50)	(33.10-68.50)	(19.60-26.40)	(11.30-14.50)	(53.00-60.40)	(90.46-96.50)	(59.18-93.24)	(10.75-18.90)	(898.68-1426.26)	(21.10-43.00)
ICSB-37	141.92	6.79	70.83	52.63	25.67	12.33	56.63	89.85	46.47	14.89	1175.70	34.90
	(116.5-166.0)	(5.65-8.10)	(65.00-80.00)	(20.20-69.90)	(19.20-29-70)	(8.70-15.20)	(37.90-66.30)	(80.65-97.44)	(17.19-83.0)	(13.35-17.90)	(583.52-1862.79)	(17.35-55.80)
27B	93.65	6.47	71.75	33.02	21.27	10.15	41.02	95.95	60.56	10.53	1145.64	24.20
	(69.5-128.0)	(5.30-8.30)	(65.50-82.00)	(12.70-44.80)	(14.70-30.40)	(8.70-12.70)	(27.70-60.20)	(92.97-97.98)	(45.15-70.60)	(7.85-12.10)	(468.47-1572.12)	(9.38-36.40)
101B	78.78	5.22	70.92	27.38	18.98	9.53	39.02	94.77	56.70	13.01	759.96	19.85
	(61.60-95.50)	(4.30-5.90)	(66.50-79.50)	(18.30-37.10)	(15.40-21.40)	(7.20-11.00)	(28.30-47.50)	(87.68-99.40)	(57.00-77.79)	(11.50-14.60)	(450.21-894.17)	(11.15-24.35)
BRJ 204B	183.75	8.06	73.58	60.73	16.02	13.08	57.87	97.00	67.38	15.00	1639.94	50.98
	(134.0-218.0)	(6.80-9.00)	(66.50-86.00)	(17.40-89.90)	(11.30-18.40)	(8.40-16.60)	(31.30-79.00)	(94.81-98.71)	(58.50-77.23)	(12.80-17.80)	(359.19-2435.38)	(11.45-80.20)
SPV-570	198.00	8.05	72.00	56.98	18.45	14.08	55.27	97.18	74.78	17.03	1406.19	49.38
	(151.50-238.0)	(7.15-9.00)	(85.50-79.50)	(21.20-81.60)	(13.50-21.30)	(8.80-17.00)	(36.60-65.20)	(94.87-98.57)	(56.00-91.21)	(14.05-20.05)	(390.81-2034.39)	(13.25-68.85)
BRJ 62	165.17	7.76	74.08	46.22	16.32	13.10	48.95	95.36	73.95	16.35	1196.71	39.66
	(129.0-203.0)	(6.65-9.30)	(68.50-81.00)	(29.30-59.30)	(13.00-20.80)	(10.80-15.20)	(40.70-57.90)	(87.67-98.72)	(48.90-86.01)	(13.08-19.30)	(640.09-1638.71)	(20.90-63.25)
R-354	164.92	7.84	74.92	61.17	19.20	13.00	52.36	93.22	82.23	14.23	1744.81	50.80
	(120.50-190.50)	(7.00-8.50)	(69.50-81.50)	(19.10-97.20)	(12.80-24.0)	(7.80-18.00)	(31.60-63.25)	(80.23-96.65)	(73.70-86.85)	(12.50-16.10)	(509.02-2979.30)	(13.95-90.95)
C-43	109.78	6.96	74.42	43.00	20.97	11.66	43.60	94.36	64.38	16.69	1102.16	35.90
	(73.90-133.0)	(6.30-8.45)	(67.50-86.50)	(16.00-59.90)	(14.40-23.80)	(8.00-14.30)	(25.60-55.50)	(90.62-98.29)	(52.25-91.19)	(13.85-19.10)	(263.57-1484.60)	(8.90-50.80)
RS 29	136.10	7.33	75.17	62.15	19.48	12.83	55.60	96.91	71.71	12.44	1766.11	47.05
	(103.0-159.0)	(6.00-8.80)	(68.00-83.50)	(11.70-94.00)	(11.10-24.10)	(7.30-16.20)	(32.00-70.60)	(94.96-99.62)	(58.80-78.24)	(10.30-15.55)	(385.44-3365.81)	(7.70-79.00)

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AKR-150	96.85 (69.25-123.50)	6.42 (6.80-7.30)	74.17 (72.00-78.50)	38.28 (11.50-56.00	21.63 (12.10-26.40)	11.84 (7.15-17.00)	47.98 (31.00-62.05)	87.53 (79.92-95.15)	45.24 (9.15-85.69)	12.38 (10.80-14.75)	1157.74 (570.41-1603.19)	28.98 (13.25-40.85)
RS 585	171.42 (143.50-190.0)	7.47 (6.15-9.50)	71.33 (68.50-76.00)	60.69 (30.40-93.70)	18.67 (13.70-21.80)	14.43 (9.90-17.30)	56.12 (37.60-69.20)	96.48 (92.43-99.60)	74.18 (65.05-94.42)	17.43 (14.55-19.15)	1526.89 (654.86-2068.95)	54.04 (21.50-80.80)
R-16	168.76 (112.50-209.50)	7.04 (6.30-8.00)	72.55 (63.00-78.00)	57.67 (24.80-81.20)	19.12 (14.50-24.20)	13.23 (9.00-16.70)	56.88 (38.30-72.90)	93.74 (89.31-97.43)	59.15 (45.35-75.95)	15.03 (12.10-18.28)	1466.2 (496.67-2051.82)	43.57 (13.65-64.05)
B-35	92.89 (73.20-102.55)	6.94 (5.65-7.80)	73.17 (64.50-82.00)	35.62 (14.50-51.00)	20.88 (14.70-26.20)	11.20 (8.00-14.10)	44.25 (29.30-55.10)	94.61 (91.48-96.48)	61.00 (41.11-88.49)	13.22 (11.60-14.85)	1014.58 (274.86-1633.70)	26.47 (7.06-41.15)
RSG-03123	124.40 (76.80-166.0)	7.22 (6.50-7.80)	71.42 (64.50-76.50)	41.97 (1.20-59.50)	19.33 (13.70-22.50)	12.69 (7.10-17.65)	47.48 (30.70-56.40)	93.52 (79.29-98.44)	49.14 (25.50-70.00)	15.08 (12.55-18.00)	832.91 (271.89-1307.90)	25.79 (7.40-41.65)
BRJ-358	183.08 (135.50-216.0)	8.64 (7.50-9.45)	76.75 (70.50-86.50)	66.62 (18.25-106.90)	13.03 (10.20-15.30)	15.27 (10.10-21.00)	55.90 (30.60-65.40)	97.49 (95.65-99.72)	83.66 (75.64-90.42)	15.01 (13.50-17.05)	1822.55 (347.98-2790.67)	54.29 (9.95-75.15)
CSV 216R	200.92 (144.50-228.50)	8.18 (7.15-9.45)	78.33 (70.50-85.50)	79.13 (30.20-114.70)	19.15 (14.70-21.90)	15.05 (11.30-18.60)	63.52 (40.10-82.10)	97.48 (97.07-98.12	83.31 (75.96-95.12)	16.31 (14.35-18.00)	1809.50 (461.04-2535.54)	58.14 (16.65-83.50)
DSV-5	187.67 (146.50-229.50)	8.20 (6.50-9.15)	77.83 (70.50-86.00)	60.65 (16.00-100.20)	18.95 (13.00-22.60)	13.38 (8.90-16.70)	55.72 (34.00-70.80)	96.72 (94.67-98.10)	85.84 (74.20-92.82)	16.65 (12.96-18.35)	1564.03 (203.43-2867.34)	49.15 (7.40-74.50)
DSV-4	192.92 (155.0-223.50)	8.18 (6.30-10.25)	77.42 (70.00-81.50)	59.50 (26.30-80.60)	22.25 (16.90-25.90)	13.87 (9.50-18.10)	57.42 (40.30-64.50)	95.59 (88.59-98.59)	80.46 (70.88-90.83)	16.95 (14.00-19.05)	1367.67 (500.92-1965.40)	47.49 (14.30-68.20)
M35-1	179.98 (149.50-196.0)	8.20 (7.50-9.50)	73.25 (67.00-78.50)	54.18 (37.20-58.20)	17.23 (14.15-19.70)	14.04 (12.60-15.90)	55.20 (46.80-63.70)	97.17 (95.26-98.57)	67.59 (17.00-93.27)	16.70 (13.95-18.55)	1378.99 (741.83-1640.20)	44.92 (26.05-59.60)
DSH-4	195.08 (133.0-231.50)	7.35 (6.30-8.95)	69.83 (66.00-75.50)	54.45 (30.30-72.20)	21.33 (16.20-23.90)	12.63 (9.90-13.70)	54.97 (43.70-61.40)	94.08 (90.69-96.26)	72.22 (63.30-83.49)	15.08 (14.15-16.70)	1430.04 (609.46-1878.35)	43.93 (19.80-62.40)
BRJ H 129	179.17 (119.50-218.5)	7.77 (6.80-9.10)	70.17 (64.00-78.00)	69.40 (34.20-95.40)	20.92 (15.80-24.80)	14.03 (10.50-17.00)	60.00 (42.90-75.90)	95.10 (92.18-97.90)	83.66 (75.03-92.11)	15.40 (13.85-17.55)	1697.48 (679.38-2538.01)	52.43 (21.90-89.00)
CSH-14	134.05 (82.50-161.0)	6.38 (5.65-6.95)	68.83 (61.50-76.50)	43.43 (19.00-70.00)	24.58 (18.80-29.10)	11.62 (8.30-13.70)	47.30 (33.70-62.70)	95.39 (92.68-97.07)	58.11 (29.25-88.92)	13.42 (11.30-16.05)	1265.63 (636.52-2317.08)	33.48 (15.50-57.60)
CSH-16	151.28 (114.65-177.50)	7.25 (6.45-7.95)	70.00 (62.50-78.00)	66.08 (29.40-95.40)	23.33 (17.70-27.30)	13.50 (10.80-16.80)	56.17 (47.40-63.10)	84.53 (75.67-88.54)	46.73 (31.10-79.20)	17.21 (15.05-20.95)	1569.33 (688.21-2232.63)	54.15 (22.20-80.50)
DSH-3	136.67 (115.50-150.50)	5.91 (4.95-7.30)	67.50 (59.00-80.00)	58.15 (33.20-75.60)	21.17 (16.60-24.60)	13.08 (9.80-15.30)	58.35 (49.80-63.59)	93.57 (85.95-98.35)	68.71 (60.50-80.99)	14.14 (12.20-16.00)	1542.25 (1076.89-2211.69)	43.47 (26.30-64.55)
CSH 15R	177.83 (136.0-200.0)	7.74 (7.00-8.95)	70.58 (63.50-77.00)	63.33 (31.90-86.90)	23.91 (19.40-28.75)	13.28 (10.20-15.60)	54.64 (43.30-63.70)	84.64 (75.18-90.26)	70.38 (56.09-86.74)	15.72 (15.35-17.10)	1658.33 (876.45-2559.84)	52.51 (25.40-86.35)
CSH 19R	172.83 (103.0-199.50)	7.28 (6.65-8.95)	70.33 (62.50-76.50)	76.41 (28.80-118.30)	23.91 (19.40-28.75)	14.98 (10.00-17.20)	59.28 (49.70-60.40)	82.00 (72.66-89.79)	66.70 (49.23-83.00)	15.80 (12.10-17.90)	1921.24 (998.96-2595.69)	65.51 (24.20-117.40)

PH- Plant height(cm),NLS- No. of leaves, D 50%F -Days to 50% flowering, PW -Panicle weight (g), PL -Panicle length (cm), PD -Panicle diameter (cm), NP -No. of primaries /panicle, PF(%)-Pollen fertility (%),SS(%)-Seed set (%),TW -500 seed weight (g), NS -No. of seeds/ panicle, YPP -Yield (g/plant)

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Table 3. *Comparative mean performance of maintainers, restorers, stay green lines, varieties and hybrids for different character across six dates of sowing*

S. No.	Genotypes	Plant height (cm)	No. of leaves	Days to 50% flowering	Panicle weight (g)	Panicle length (cm)	Panicle diameter (cm)	No. of primaries panicle^{-1}	Pollen fertility (%)	Seed set (%)	500 seed weight	No. of seeds panicle^{-1}	Yield (g plant^{-1})
1	B lines (13)	131.6	6.5	72.5	46.9	21.8	12.4	50.6	93.3	65.4	13.5	1261.6	34.2
2	R line (9)	144.9	7.5	73.9	54.8	18.5	13.3	52.5	94.7	69.9	15.2	1465.5	44.9
3	Stay green lines (2)	108.6	7.1	72.3	38.8	20.1	11.9	45.9	94.1	55.1	14.2	923.7	26.1
4	Varieties (4)	190.4	8.2	76.7	63.4	19.4	14.1	58.0	96.7	79.3	16.7	1530.0	49.9
5	Hybrids (7)	163.8	7.1	69.6	61.6	22.7	13.3	55.8	89.9	66.6	15.3	1583.5	49.4

Table 4: Genotypes showing less range of variation across dates of sowing for four important traits in rabi sorghum

Characters		Narrow range					Max. range
	Genotype	116 B	B 35	296 B	104B	DSH 3	BRJH129
Plant height (cm)	Range	108.50 -134.50	73.20-102.55	107.50-139.50	117.50-150.0	115.50-150.50	119.5-218.85
	Mean	119.2	92.89	129.08	134.75	136.67	179.17
Days to 50%	Genotype	296B	AKR-150	RS 585	DSH 4	M35-1	DSH3
flowering	Range	73.00-77.0	72.00-78.0	68.50-76.0	70.00-81.50	67.00-78.50	59.00-80.00
	Mean	74.17	74.17	71.33	69.83	73.25	67.50
Seed set	Genotype	R-354	BRJ-358	BRJH 129	116 B	401 B	AKR150
percentage(%)	Range	73.70-86.85	75.64-90.42	75.30-92.11	77.25-94.70	48.70-66.72	9.15-85.69
	Mean	82.23	83.60	83.66	82.61	65.71	71.71
Grain yield	Genotype	AKMS14B	101B	296B	116B	BJMS 2B	CSH19R
plant^{-1} (g)	Range	18.50-31.40	11.50-24.35	23.80-37.30	20.00-38.10	21.10-43.00	24.20-117.40
	Mean	24.50	19.85	29.31	33.70	34.68	65.51

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height suited to irrigated condition or paddy fallow ecosystem. Similarly, for days to 50% flowering, the genotypes 296B, AKR150, R 16, DSH4 and M35-1 exhibited a narrow range compared to the highest range recorded by DSH3 across dates of sowing and temperature regimes indicating that these can be used to develop genotypes for late sowing. The narrow range of mean seed set percentage was observed in R-354, BRJ 358, BRJH 129 and 401B compared to the highest range recorded by AKR150 indicating that these are less sensitive to temperature variations. Similarly, the genotypes AKMS14B, 101B, 296B, 116B and BJMS2B registered narrow range of mean grain yield per plant compared to the highest range recorded by CSH-19R across sowing dates and temperature regimes. These results revealed that the above genotypes could be used further for the development of new breeding lines which are less sensitive to sowing dates and temperature regimes in *rabi* season.

The present study indicated that, pollen fertility decreased much when temperature goes below 10-13°C. Some of the genotypes viz., BRJ-358, CSV216R, SPV-570 and M35-1 are less sensitive to low temperature and this can be utilized in the breeding program to improve the efficiency of pollen fertility. Genotypes which recorded consistent yield performance throughout the different dates of sowing viz., AKMS14B, 101B, 296B, 116B and BJMS2B can be used in crop improvement program to develop genotypes for late sowing.

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Shift in Character Association under Different Water Stress Environments in Sunflower (*Helianthus annuus* L.)

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Abstract: The present investigations were undertaken to find out association among the economically important characters in different moisture regimes. Under normal irrigation level, seed yield exhibited significant positive correlation with 100-seed weight, early vigour and photosynthetic capacity, however, its association with canopy temperature was significantly negative. The significant positive association of seed yield with 100 seed weight, leaf water potential, plant height and head diameter was observed in second water stress environment. In third water stress environment, seed yield had significant positive correlation with early vigour, canopy temperature, head diameter and 100-seed weight but a significant negative correlation with leaf area index and number of days to maturity. In fourth stress condition, seed yield was found to have significant positive association with head diameter, 100 seed weight and leaf water potential. This indicated a shift in correlations under changing water stress environments. The study revealed that while selecting for high seed yield under different water stress conditions, the selection criteria should be based on the changing correlations among different characters, under different stress environments.

Key Words: Correlation, photosynthetic capacity, canopy temperature, leaf water potential

Breeding for high yielding crop varieties requires information on association of component characters with yield and among themselves. Yield, under stress, can be considered as a function of yield potential, maturity and susceptibility index. Depending upon the timing and intensity, water stress could decrease yield directly by affecting grain setting or grain filling rate or indirectly by decreasing leaf expansion and photosynthesis or increasing leaf senescence. Practical selection for drought tolerance frequently relies on the use of a selection index of secondary traits as well as grain yield. The use of secondary traits is considered beneficial when the trait can be identified prior to flowering or can be measured more rapidly and easily than yield or when the trait is strongly correlated with yield with high heritability. However, most of the characters of economic interest show polygenic inheritance, hence their correlation changes with changing environments. There are many reports available on correlation studies for morphological, physiological and yield characters in sunflower (*Helianthus annuus* L.) in a particular environments, however, the studies related to shift in character association over environments (particularly water stress environments) is not available. Keeping this into consideration, the present work was planned with the objective to study the change in association of different traits influencing yield, under different stress environments.

MATERIAL AND METHODS

The experiment was conducted at the Punjab Agricultural University, Ludhiana, India. The experimental material comprised of 41 lines of sunflower comprising 16 maintainer lines and 25 restorer lines planted during spring season 2009 in a randomized block design with three replications. Each parental line was represented by a plot of two rows of 3m length. The inter and intra-row spacing was maintained at 60 cm and 30 cm, respectively. The experiment was repeated four times to create four different environments by providing following irrigation regimes:

W_1 (Irrigation level 01) : Irrigating the plots during the entire growth cycle to maintain the soil water content close to field capacity.

W_2 (Irrigation level 02): Withholding of 2nd irrigation i.e. before button stage and there after complete withholding of irrigations after soft dough stage.

W_3 (Irrigation level 03): Withholding of irrigation at 50 per cent flowering stage and soft dough stage, thereafter complete withholding of irrigations after hard dough stage.

W_4 (Irrigation level 04): Withholding of irrigation at anthesis completion stage and there after complete withholding of irrigation after soft dough stage.

The list of genotypes evaluated is given in table 1. Two seeds were dibbled in each hill to facilitate better emergence and to provide uniform plant stand. A recommended manure dosage was applied. Thinning was attended to 15 days after sowing to retain one plant per hill. The plants were grown under protective irrigation. All the recommended

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agronomic practices were followed to facilitate good growth and to raise a successful crop. From each line in each replication, five competitive plants were tagged at random. Except for early vigour and days to 50% flowering, all other observations on quantitative characters were recorded at maturity. The mean data of all the characters was subjected to statistical analysis.

Phenotypic and genotypic correlation coefficients were worked out by the formulae suggested by Al Jibouri *et al.* (1958). The significance of phenotypic correlation coefficients were tested against r values from the r table of Fisher and Yates (1963) at P = 0.05 and P = 0.01.

RESULTS AND DISCUSSION

The correlation values of different parameters under individual stress level have been presented in Table 2-5 for reference. Under pooled over environments (Table 6), days to 50 per cent flowering had positive and significant positive correlation with days to maturity, plant height and leaf area index. Days to maturity has positive association with 100-seed weight but as reported earlier (Kaya *et al.*,2007) correlated negatively with oil content. Seed yield had significant positive correlation with head diameter, 100 seed weight and leaf water potential as discussed by Khan *et al.* (2003). 100 seed weight exhibited the highest negative direct load on oil content, which was fully in accordance with the results of correlation analysis discussed by Iqbal *et al.* (2009). Oil content recorded significant positive correlation with photosynthetic capacity and a positive and non-significant association with seed yield per plant as reported by Iqbal *et al.* (2005). But, contrary to our results Ashoke *et al.* (2000) have reported positive and significant correlation of oil content with achene yield.

Further, it was observed that there was change in correlations among different characters with the change in irrigation schedule (stress environment).

In W_1, days to 50 per cent flowering showed significant positive correlation with days to maturity, photosynthetic capacity and leaf water potential, while in W_2, W_3 and W_4 this association was non-significant (Table 2-5). In W_3, days to 50 per cent flowering had significant positive correlation with leaf area index, which was non-significant in case of W_1. Days to maturity was observed to have significant positive correlation with leaf area index in control (W_1), while in W_2 and W_4 there was no association among these characters. Plant height exhibited positive significant correlation with head diameter and seed yield per plant only in W_2 and non-significant in other stress treatments. Whereas, with leaf water potential, it (plant height) showed positive correlation in W_1, W_3 and W_4 and non-significant in W_2; with early vigour, positive correlation in W_1 and W_3 but non-significant in W_2 and W_4; with photosynthetic capacity positive correlation in W_1 and non-significant in other treatments. Head diameter had significant positive correlation with early vigour and canopy temperature in W_1 only, which was non-significant in other stress treatments (W_2, W_3 and W_4). There was significant positive association of canopy temperature with head diameter and leaf water potential in W_1, whereas, non-significant in W_1, W_2 and W_3.

In control (W_1), seed yield had significant positive correlation with early vigour, canopy temperature and photosynthetic capacity, whereas, in W_2 no correlation with above parameters was recorded except with leaf water potential. In W_3, it did not have any correlation with photosynthetic capacity and leaf water potential while in W_4 positive correlation with leaf water potential was observed.

Table 1. List of genotypes

S.No.	Inbred line	S.No.	Inbred line	S.No.	Inbred line
1	P-61-R	17	P-112-R	33	47-B
2	R-273	18	P-115-R	34	48-B
3	P-93-R	19	P-119-R	35	49-B
4	95-C-1-R	20	P-121-R	36	50-B
5	P-91-R	21	P-124-R	37	52-B
6	P-107-R-P_1	22	NDLR-2	38	53-B
7	P-107-R- P_2	23	NDLR-1	39	36-B
8	P-69-R	24	44-B	40	RCR-8297
9	3376-R	25	40-B	41	RHA-297
10	P-100-R	26	10-B		
11	P-110-R	27	234-B		
12	P-87-R	28	11-B		
13	P-89-R	29	304-B		
14	P-75-R	30	395-B		
15	P-94-R	31	7-1-B		
16	P-111-R	32	45-B		

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Table 2. Correlations among different characters at irrigation level 01 (W_1)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.1879*	0.4819**	0.1312	0.0468	0.1469	-0.1001	0.0607	-0.0527	0.2385**	0.0914	0.2676**
DM	0.1934		0.0061	0.0139	-0.0162	0.0574	-0.1515	0.1116	-0.2484**	0.0509	0.2484**	0.2594**
PH	0.5006	0.0107		0.0472	0.1516	0.0134	-0.0896	0.1860*	-0.1560	0.2147*	0.0215	0.2386**
HD	0.1416	0.0285	0.2456		0.6333**	0.4945**	-0.0150	0.1761*	-0.1951*	0.0854	-0.0562	0.0841
SY	0.0550	-0.0120	0.1533	0.6751		0.2708**	-0.1348	0.2353**	-0.2471**	0.2309**	0.0924	0.1568
SW	0.1648	0.0900	0.0089	0.5499	0.2781		-0.0223	0.0971	-0.0772	0.1789*	-0.0726	0.0390
OC	-0.0938	-0.1654	-0.1276	-0.0873	-0.1837	-0.0424		0.0451	-0.0709	0.0787	0.1999*	0.0687
EV	0.0863	0.0434	0.1857	0.1153	0.3223	0.1355	0.2393		0.0377	0.0889	0.1148	-0.0454
CT	-0.1085	-0.4880	-0.0497	-01793	-0.3712	-0.1065	-0.2397	0.0857		0.1037	-0.0689	0.0529
PS	0.3326	0.1995	0.2086	0.1796	0.3418	0.1835	0.1918	0.1356	0.2358		0.0847	-0.5000**
LAI	0.1080	0.2166	0.0283	-0.0569	0.1974	0.2879	0.1625	0.2173	-0.1263	0.1061		-0.2860**
LWP	0.5352	0.7728	0.1916	0.6453	0.8271	0.2549	0.2388	-0.5075	-0.3420	-0.5187	-0.1726	

*Above diagonal value indicate phenotypic correlation & below diagonal value indicate genotypic correlation

Critical value of 'r' at 5%= .1761 and that at 1%= .2289

*, ** - significant at 5 % and 1 % level respectively

DF: Days to 50% Flowering; DM: Days to maturity; PH: Plant height ; HD : Head diameter ; SY : Seed yield per plant ; SW : 100 Seed weight; OC : Oil content ; EV : Early vigour ; CT : Canopy temperature ; PS : Photosynthetic capacity ; LAI : Leaf area index ; LWP : Leaf water potential.

Table 3. Correlations among different characters* at irrigation level 02 (W_2)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.0543	0.4520**	0.1313	0.0428	0.1468	-0.0676	0.0859	0.0060	0.0205	0.0871	0.0754
DM	0.0825		-0.0967	0.1286	0.0468	0.0842	-0.1167	-0.0879	-0.1957*	0.0786	-0.1104	0.1569
PH	0.4753	-0.1343		0.3253**	0.1981*	-0.0445	-0.0093	0.0376	-0.0258	0.1262	-0.0680	0.1277
HD	0.1556	0.1293	0.3362		0.5956**	0.4772**	-0.0264	0.1217	-0.0472	-0.0809	-0.1322	0.1786*
SY	0.0434	0.0636	0.2011	0.6185		0.2708**	-0.1348	-0.0289	-0.0407	-0.0512	-0.0890	0.2812**
SW	0.1519	0.0802	-0.0359	0.4981	0.2781		-0.0223	0.2051**	0.0019	-0.2011*	-0.1165	0.2334**
OC	-0.1208	-0.1498	-0.0258	-0.0492	-0.1837	-0.0424		0.2245**	0.0127	-0.0477	0.1134	-0.2037*
EV	0.0992	-0.1904	0.0655	0.1408	-0.0399	0.2547	0.5054		-0.0944	-0.0312	-0.0963	-0.1589
CT	-0.0043	-0.2434	-0.001	-0.0808	-0.0656	-0.0064	0.0729	0.0087		-0.1876*	-0.1433	-0.0278
PS	0.0167	0.1181	0.1623	-0.0923	-0.0643	-0.2264	-0.0488	-0.0988	-0.2589		-0.0304	-0.0363
LAI	0.0572	-0.2299	-0.1106	-0.1874	-0.1042	-0.1410	0.1944	-0.2692	-0.2144	-0.0819		-0.1786*
LWP	0.1073	0.2181	0.1549	0.2092	0.3118	0.2498	-0.3567	-0.2302	0.0437	-0.0992	-0.2229	

*See table 2 for details

Table 4. Correlations among different characters* at irrigation level 03 (W_3)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.0936	0.4019**	0.1548	-0.0706	-0.0009	-0.0748	0.1054	-0.0600	0.0621	0.1826*	0.0100
DM	0.0772		0.1576	0.0583	-0.2503**	0.1252	0.1029	0.0384	-0.0302	0.0466	0.0628	0.0418
PH	0.4273	0.1605		0.1551	-0.0785	-0.0519	-0.1230	0.2461**	0.0049	-0.0367	0.0408	0.2122**
HD	0.1729	0.059	0.1657		0.5190**	0.4840**	-0.0209	-0.1151	0.0484	0.0559	0.0111	0.0599
SY	-0.0743	-0.2688	-0.0807	0.5503		0.3430**	0.1047	0.2291**	0.1875*	-0.0419	0.1793*	0.0684
SW	0.0045	0.1591	-0.0569	0.5697	0.3675		0.0235	0.0464	0.0339	0.0446	-0.1445	-0.0486
OC	-0.1391	0.122	-0.1953	-0.0511	-0.1505	0.0133		0.0855	-0.0088	-0.0117	0.1849*	0.0142
EV	0.1653	0.0784	-0.3668	-0.1391	-0.3386	0.0441	0.2845		-0.0737	-0.0352	0.1002	0.0600
CT	-0.1203	-0.0295	0.0137	-0.0283	0.3135	0.1297	-0.0049	-0.2396		0.0978	-0.1294	0.0023
PS	0.6065	0.484	-0.3712	0.3182	-0.079	0.5109	0.3257	-0.5045	0.1988		-0.0298	0.0176
LAI	0.2199	0.0752	0.0425	0.0178	0.2211	-0.1823	0.2642	0.1535	-0.1609	-0.4446		0.0421
LWP	0.0061	0.2557	0.2898	0.0709	0.1005	-0.0527	-0.1366	-0.1038	0.0972	-0.9313	0.0557	

*See Table 2 for details

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Table 5. Correlations among different characters* at irrigation level 04 (W_4)

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.1502	0.4739**	0.1279	-0.0061	0.0477	0.0118	0.0007	-0.1004	-0.0161	0.1539	-0.0196
DM	0.1813		0.0385	0.1260	0.1166	0.0720	-0.0589	-0.2537**	0.0649	0.0554	-0.0438	0.1278
PH	0.5035	0.0429		0.0675	0.0733	-0.0095	0.0891	0.0235	0.0504	0.0426	0.0856	0.1928*
HD	0.1351	0.1432	0.0764		0.5701**	0.4562**	0.1524	0.1065	-0.2948*	-0.0269	-0.0981	-0.0238
SY	-0.0006	0.1131	0.0738	0.6015		0.2594**	0.1420	-0.0625	-0.1509	-0.0870	-0.0430	0.1961*
SW	0.0519	0.0967	-0.0105	0.4831	0.2700		0.2432**	0.1337	-0.2906**	-0.1750	-0.1497	0.2258*
OC	0.0246	-0.1022	0.096	0.1894	0.1481	-0.2917		-0.0062	-0.0137	0.2081*	0.1615	0.1061
EV	0.0299	-0.3263	0.0355	0.1435	-0.0751	0.1615	-0.0532		-0.0926	-0.0510	-0.2821**	-0.0597
CT	-0.1254	0.0292	0.0487	-0.4027	-0.2108	-0.4148	0.0296	-0.1886		-0.0290	0.2053*	0.0115
PS	-0.0830	0.1608	0.0495	-0.0142	0.1305	0.2507	0.3822	-0.0902	-0.0127		0.1955*	-0.0426
LAI	0.1551	-0.0482	0.0986	-0.0884	-0.0587	-0.1738	0.1700	-0.3922	0.2898	0.2586		-0.0769
LWP	0.0171	0.1624	0.3882	0.1092	0.2901	0.0739	0.2830	-0.0710	0.1022	-0.0659	-0.1468	

*See Table 2 for details

Table 6. Correlations among different characters* pooled over environments

	DF	DM	PH	HD	SY	SW	OC	EV	CT	PS	LAI	LWP
DF		0.1927*	0.5081**	0.1607	0.0012	0.1351	-0.1125	0.0602	-0.0262	-0.1541	0.1977*	0.1386
DM	0.2020		0.0377	0.0876	-0.0597	0.1715*	-0.1819*	-0.1785	-0.0746	0.0857	-0.0704	0.0904
PH	0.5131	0.0384		0.1508	0.0982	0.1342	-0.1150	-0.1485	-0.0851	-0.1347	0.0261	0.2831**
HD	0.1640	0.0827	0.1502		0.6310**	0.3820**	-0.1318	0.0236	-0.1447	0.0191	-0.0387	0.1018
SY	0.0034	-0.0611	0.0987	0.6392		0.2508**	-0.1340	-0.1770*	-0.1447	0.0191	-0.0387	0.1018
SW	0.1712	0.1002	-0.0359	0.4056	0.2401		-0.0424	0.1355	-0.1743*	0.0644	-0.0892	0.1555
OC	-0.1215	-0.1015	-0.0196	-0.0498	-0.1890	-0.2015		0.2393**	-0.0064	-0.2264**	-0.1823*	-0.0527
EV	0.0871	-0.1203	-0.2128	0.0038	-0.2348	0.2140	0.2492		0.1120	0.0137	-0.1141	-0.0408
CT	-0.0496	-0.0483	-0.1031	-0.1729	-0.2089	-0.1514	-0.2151	0.1879		0.0023	-0.1162	0.1370
PS	-0.2670	0.1307	-0.2185	0.0344	0.1170	-0.1950	0.1842	-0.0927	-0.2054		-0.0072	0.0551
LAI	0.2207	-0.0941	0.0292	-0.0375	-0.0966	-0.1693	0.1321	-0.1751	-0.1986	-0.0788		0.0106
LWP	0.5970	0.3116	1.0564	0.3818	0.6313	0.2351	0.2422	-0.4638	0.4689	0.2025	0.9240	

*See Table 2 for details

100 seed weight was associated positively with photosynthetic capacity in case of W_1 and W_2; whereas, in W_3 and W_4; there was no association. Oil content correlated positively with leaf area index in W_1 and W_3 however, W_2 and W_4 it was non- significant. Oil content correlated positively with early vigour in W_2 only while in other environment it was non-significant.

On the basis of present study, it can be concluded that shift in correlations among various parameters occurs with changing environments and under normal irrigation level, the yield potential of genotypes could be improved by direct selection for early vigour, 100 seed weight, photosynthetic capacity, leaf area index and leaf water potential, while under water stress conditions, direct selection for head diameter, delayed flowering, leaf water potential and 100 seed weight could improve the yield ability.

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Influence of Tillage and Weed Management on Soil Properties of Rice Fields

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Abstract: A field study was conducted in a rice – wheat cropping system, rotated for three consecutive years with different tillage systems vis-à-vis weed control practices. In the fourth year of study, their effect was evaluated in terms of physico-chemical, bio-chemical and microbiological properties of rice rhizosphere soil. The results of the investigation revealed that different type of tillage operations exhibited their effects on physio-chemical properties, organic carbon status, enzymes' activity, basal respiration rate and microbial population of rhizosphere soil of rice. Soil reaction (pH) tend towards normality due to conventional-conventional tillage system, however, EC was least affected by different tillage systems. Maximum organic carbon was found in rhizosphere soil under conventional-conventional tillage system. It was found that soil enzymes' activity and basal soil respiration was maximum under conventional-conventional tillage system, whereas, minimum under zero-zero tillage system. The acid phosphatase activity was found more than alkaline phosphatase activity. The microbial population study showed that conventional-conventional tillage system promoted the growth of fungal and bacterial population whereas zero-zero tillage system did not show any promotional activity of the concerned microbial population. Data of above microbial population were also supported by microbial biomass carbon status of soil. The results of weed management study envisaged that the use of recommended herbicides (Butachlor as pre-emergence and fenoxaprop-p-ethyl + ethoxysulfuron as post-emergence) significantly affected the EC, organic carbon status, enzymes activity (acid, alkaline phosphatase and dehydrogenase), basal soil respiration rate, microbial population and microbial carbon status in rhizosphere soil of rice. The above parameters were found significantly lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth periods of crop.

Key Words: Tillage system, rice, herbicide, phosphatase, dehydrogenase enzyme

In India, rice-wheat cropping system is most commonly adopted cereal based cropping system. There are several techniques are adopted by the farmers for rice sowing as per their feasibility and resource availability. Line sowing is one of them, which is not only economical but also time saver. The most common problem associated with this system is the density of weed flora. Different tillage practices vis-à-vis herbicides are adopted by the rice growers to minimize the above problem. These tillage practices have been shown to alter the chemical and microbiological properties of soils, which is supposed to create a great impact on agricultural production (Ferreira *et al.*, 2000). Generally herbicides are not harmful when it is applied in recommended levels in soil but reports show that herbicidal application has adverse effect on microbial activities and microbial population. However, the effect of herbicide application under different tillage systems was not adequately studied elsewhere. Therefore, the present study was conducted to evaluate the influence of different tillage systems on herbicide degradation in terms of microbial population, their different activities in rhizosphere of rice and other soil properties.

MATERIAL AND METHODS

Rice-wheat cropping system was rotated for four consecutive years (2005-2008) at research farm of Indira Gandhi Agricultural University, Raipur and during the fourth year a study was conducted to find out the effect of different tillage systems and weed control practices on soil properties of rice rhizosphere. Four types of tillage systems (*kharif* followed by *rabi*) viz. (i) conventional-conventional (ii) conventional-zero (iii) zero-conventional and (iv) zero-zero were evaluated and put in main plots. Among weed control measures performance of hand weeding and recommended herbicidal application (Butachlor as pre emergence @1.5 kgha^{-1} and fenoxaprop-p-ethyl and ethoxy sulfuron as post emergence herbicide @ 56.25 and 15.00 gm ha^{-1}, respectively) were compared with weedy check and put in sub plots. The pre emergence and post emergence herbicides were applied at 3 and 20 days after sowing of the crop, respectively. The experiment was conducted on *Kharif* rice (*Oryza stativa* L.) with test variety MTU-1010. The soil was Inceptisol (pH : 6.7, EC : 0.16 m mhos cm^{-1}, organic carbon : 0.50%, available N: 220.50 kg ha^{-1}, available P: 14.42 kg ha^{-1} and available K : 348.00 kg ha^{-1}). The treatments were replicated thrice under split plot design. Rhizosphere

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soil was collected at a depth of 7.5-15 cm from six locations at different stages of crop growth from the same plot and pooled together for the purpose of analysis. Soil sampling was done at 30, 50 days after sowing of crop and harvest stage of crop. The soil samples were subjected to analysis for pH, EC, organic carbon (OC), phosphatase (Acid P and Alk P) and dehydrogenase (DHA) activity, basal respiration rate (BSR), microbial population (bacteria and fungi) and microbial biomass carbon content (MBC). The estimation of total bacteria (TB) and fungi in soil was done by serial dilution technique and pour plate method (Pramer and Schmidt, 1965). Enumeration of bacteria was done on Nutrient Agar and fungi on Rose-Bengal agar (Martin, 1950). EC was determined by conductivity bridge method (Jackson,1973), organic carbon content in soil by rapid dichromate oxidation, basal soil respiration by measuring the CO_2 evolution rates (Anderson, 1982), biomass carbon by fumigation extraction method (Jenkinson and Powlson,1976). Enzymatic activities (dehydrogenase and phosphatase) were estimated by UV/VIS Spectrophotometer with the wavelength of 485 nm. Three per cent solution of TTC (triphenyl tetrazolium chloride) and 0.025M p-nitrophenyl phosphate were used as a substrate to measure the activity of dehydrogenase and phosphatase, respectively.

RESULTS AND DISCUSSION

It is apparent from the results that different type of tillage operations exhibited their effect on physio-chemical properties, organic carbon status, enzymes' activity, basal soil respiration rate and microbial population of rhizosphere soil of rice (Table 1-3). It was visualized that soil reaction (pH) showed an increasing trend from 30DAS to harvest stage of the crop but it was found near to neutral in conventional-conventional tillage system at harvest stage of the crop (Table 1). EC was least affected by different tillage systems. Maximum organic carbon was found in rhizosphere soil under conventional-conventional tillage system. Ferreira *et al.* (2000) also reported relatively higher availability of soil organic matter at lower soil profile under conventional tillage, which may be due to even distribution of crop residues and other nutrients throughout the plough zone. In soil enzymatic study, it was found that the activity of phosphatase (acid and alkaline phosphatase) and dehydrogenase enzymes was found significantly higher in conventional-conventional tillage treatments compared to other three tillage treatments. The activity of above three enzymes was found lowest under zero-zero tillage treatment (Table 2). Mijangos *et al.* (2005) also concluded that biological parameters have great value as early and sensitive indicator of change in soil properties induced by different soil management strategies. During the study of basal soil respiration, it was noticed that under conventional-conventional tillage system, significantly higher CO_2 evolution was recorded compared to other tillage treatments which was an indicator of greater microbial activities under this system. Alternate conventional-zero and zero-conventional tillage systems were found at par *w.r.t.* of basal soil respiration rate during the whole crop growth stages (Table 2).

The microbial population study showed that conventional-conventional tillage system promoted the growth of fungal and bacterial population, whereas, zero-zero tillage system did not show any promotional activity of the concerned microbial population (Table 3). Singh *et al.* (2007) also found higher microbial populations under conventional tillage system at lower soil depth (7.5 to 15 cm). They also reported that at lower layer i.e., more than

Table1. Effect of tillage practices and herbicides on physico-chemical properties and organic carbon status of rhizosphere soil of rice

Treatment	Days after sowing								
	30			50			At harvest		
	pH	EC	OC(%)	pH	EC	OC(%)	pH	EC	OC(%)
Tillage									
Conventional-Conventional tillage system	6.84	0.17	0.66	6.85	0.18	0.67	6.88	0.17	0.69
Conventional-Zero tillage system .	6.76	0.19	0.63	6.77	0.20	0.64	6.79	0.18	0.66
Zero-Zero tillage system	6.59	0.16	0.46	6.59	0.17	0.47	6.62	0.16	0.49
Zero-Conventional tillage system	6.48	0.19	0.56	6.49	0.20	0.56	6.51	0.18	0.58
CD (0.05)	0.20	NS	0.02	0.19	0.02	0.06	0.22	0.02	0.01
Weed Management									
Hand weeding	6.60	0.25	0.61	6.61	0.26	0.61	6.64	0.24	0.63
Recommended herbicide application	6.58	0.18	0.50	6.60	0.18	0.50	6.61	0.18	0.52
Weedy check	6.82	0.13	0.63	6.83	0.14	0.65	6.85	0.13	0.67
CD (0.05)	0.16	0.02	0.01	0.14	0.01	0.03	0.15	0.01	0.01

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Table 2. Effect of tillage practices and herbicides on phosphatase (µg *p*-NP h^{-1} g^{-1} soil), dehydrogenase (µg TPF h^{-1} g^{-1} soil) activity and basal soil respiration rate (mg CO_2 h^{-1} $100g^{-1}$ soil) of rhizosphere soil of rice

Treatment	Days after sowing											
	30				50				At harvest			
	Acid P	Alk P	DHA	BSR	Acid P	Alk P	DHA	BSR	Acid P	Alk P	DHA	BSR
Tillage												
Conventional-Conventional tillage system	155.4	118.7	47.5	0.203	256.3	208.9	79.8	0.248	126.4	99.8	29.4	0.108
Conventional-Zero tillage system	149.0	114.5	45.1	0.189	250.8	213.3	75.0	0.232	122.2	93.5	26.6	0.098
Zero-Zero tillage system	139.4	102.8	39.2	0.180	243.2	190.6	68.6	0.224	115.3	88.6	21.4	0.090
Zero-Conventional tillage system	145.3	109.0	43.8	0.188	248.1	203.3	73.0	0.230	121.7	92.7	24.4	0.095
CD (0.05)	0.8	1.1	2.3	0.002	1.5	2.4	0.5	0.002	1.5	1.8	1.2	0.003
Weed Management												
Hand weeding	148.2	112.2	42.7	0.208	251.8	202.0	75.3	0.238	122.2	95.1	26.1	0.100
Recommended herbicide application	134.5	96.3	37.0	0.143	238.5	195.0	69.8	0.208	115.7	88.0	22.5	0.086
Weedy check	159.1	125.3	52.0	0.220	258.6	215.1	77.2	0.255	126.4	97.9	27.8	0.107
CD (0.05)	0.8	0.9	1.1	0.002	1.4	1.2	0.8	0.001	0.8	1.4	1.3	0.002

Table 3. Effect of tillage practices and herbicides on the proliferation of fungi (x 10^3), total bacteria (x 10^5) and microbial biomass carbon status (µ g) of rhizosphere soil (per gram dry soil) of rice

Treatment	Days after sowing								
	30			50			At harvest		
	Fungi	TB	MBC	Fungi	TB	MBC	Fungi	TB	MBC
Tillage									
Conventional-Conventional tillage system	100.4	113.4	194.2	135.2	159.4	251.7	67.9	70.7	81.9
Conventional-Zero tillage system .	92.7	96.7	190.8	126.0	145.7	242.4	64.3	64.3	75.2
Zero-Zero tillage system	79.3	82.9	184.0	126.5	122.6	231.0	58.4	59.6	69.4
Zero-Conventional tillage system	84.7	91.4	187.7	120.8	136.3	238.6	62.0	62.0	70.4
CD (0.05)	2.0	0.8	5.1	2.1	1.2	2.2	0.6	0.8	2.5
Weed Management									
Hand weeding	106.2	116.6	195.9	130.7	152.9	243.2	66.5	66.1	76.9
Recommended herbicide application	50.9	43.5	169.5	98.3	97.8	226.8	53.5	58.1	63.9
Weedy check	110.7	128.2	202.1	152.4	172.3	252.9	69.6	68.2	81.9
CD (0.05)	1.3	1.2	2.7	2.2	0.7	2.3	1.0	0.6	1.4

7.5 cm depth from soil surface, *Azotobacter spp.* counts were significantly higher under conventional tillage as compared to minimum tillage. Janusauskaite *et al.* (2013) demonstrated that bacteria and fungi decreased in no tillage system by 25.5 and 22.7%, respectively in comparison to conventional tillage. It can be concluded that conventional tillage system provides stimulating effects for microbial growth due to uniformly distributed residues in the arable layer and increases the rate of supplied oxygen to soil micro sites. Data of microbial population recorded under the present study were also supported by microbial biomass carbon status of soil.

The results of weed management envisaged that the use of recommended herbicides (Butachlor as pre emergence and fenoxaprop-p-ethyl and ethoxy sulfuron as post emergence herbicide) significantly affected the EC and organic carbon content in rhizosphere soil of rice (Table 1). However, soil pH was found unaffected due to application of herbicides. These observations are in close agreement with Sebiomo *et al.* (2010) who found that the herbicide treatments had significant effect on per cent organic matter of the soils treated with herbicides, which reduced significantly as compared to control. The activity of enzymes i.e. acid and alkaline phosphatase, dehydrogenase, basal

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soil respiration rate (Table 2), microbial population and microbial carbon status in rhizosphere soil of rice (Table 3) found significantly lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth period of crop.

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Bioaccumulation of Heavy Metals and its Effects on the Quality of Rice Grown in the Tannery Polluted Soils

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Abstract: This study aims to determine accumulation of heavy metals in the soil and their translocation to the rice crop grown in the fields irrigated with contaminated water of the Kalasinghia drain, which is rich in discharges from tannery units. For comparison, soil and rice plants of a tube-well irrigated field far away from the polluted field were used as control. All observations were taken from the same field and crop twice, i.e. vegetative phase of the crop (before flowering) and at the time of harvest. Physicochemical parameters of the crop were also studied. The results showed the accumulation of heavy metals in the polluted soils more than the control soils. The concentration of heavy metals in the samples was also found to be as follows soil > root > shoot > grain. A significant difference was observed between heavy metal contents in the vegetative plants and mature plants. The Cr, Cu and Ni concentrations in rice grains were more than the values permitted by international health organizations and thus not acceptable for human consumption.

Key Words: Heavy metals, rice, polluted water, quality

Tannery industry effluents are causing serious pollution in Punjab. During tannery process, a substantial amount of acids, alkalies, salts of chromium and sodium, dyes, etc. are used. Leather and sports complex located at Jalandhar is generating huge quantity of tannery effluents. The common effluent treatment plants (CETP) can treat only 1.5 million litres of discharge per day while more than 5 million litres of discharge is expelled out every day. Kalasinghia drain passing through this area carries the treated, partially treated and untreated waste waters of this sports complex.Due to lowering of water table and also shortage of power for tubewells, the irrigation of crops with the water of this drain is an easy option. The rice crop is one of the most effected crops as this crop requires more frequent irrigation. Since the rice crops have been reported to accumulate heavy metals from soil and water, this study was aimed to asses the accumulation and translocation of heavy metals fron the tanner effluent irrigated rich soil to the rice crop

MATERIAL AND METHODS

The area selected for investigation is located at village Bhudopinder about 15km away from the Jalandhar, India (31° 23' N and 75° 25' E) on Kapurthala-Jalandhar highway. The Kalasighia drain carries the effluents from leather and sports complex, Jalandhar and moves through village Bhudopinder, the one selected for investigation as polluted fields. The tubewell irrigated field at village Vandala, which is 10km away from the polluted areas on other side of Jalandhar –Kapurthala highway, was taken as control. PR118 rice cultiver was selected for investigation.

Soil analysis: From each of the selected field, one Kg of soil was taken from five randomly selected sites. Hundred grams of the soil sample was acid digested and total metal estimation was done using Inductively Coupled Argon Plasma Atomic Emission Spectrophotometer (ICAP-AES) method (AOAC, 1984).

Metal uptake in rice plant: Sampling of rice was done from same field twice i.e. pre-flowering stage (vegetative plants) and post-flowering stage (mature plants at harvest stage). The well washed plants were oven dried at 55±5° C for 24 h, grounded and kept in air tight containers. Each oven dried sample (1 g) was digested with 15 ml of diacid mixture of nitric acid and perchloric acid in the ratio of 4:1 in a conical flask. The digested samples were filtered and stored in decontaminated dried labeled and air tight polythene bottles. The samples were analyzed using ICAP-AES method (AOAC, 1984).

Biochemical analysis: The fresh leaves collected at pre-flowering and post-flowering stage were washed thoroughly to remove all traces of soil particles and were used for estimation of various nutritive constituents like total soluble proteins (Lowry *et al,* 1951), carbohydrates (Ashwell, 1957) and chlorophyll (UV-Visible Spectrophotometer (U.S. EPA, 1994). Mature grains were used for estimation of protein and carbohydrate content.

RESULTS AND DISCUSSIONS

Physical and chemical characteristics of soils: The order of abundance of metals in control fieldl was Cr>Ni>>Pb Cu>Cd. There was many fold increase in the metal

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Table 1. Physico-chemical analysis of the tannery polluted and the tubewell irrigated soils

Soil Characteristics	Control fields	Tannery polluted field
Soil texture	Sandy loam	Sandy loam
Soil pH	7.80	8.01
Cr (mg kg^{-1})	11.70	420.15
Cu (mg kg^{-1})	3.65	19.45
Ni (mg kg^{-1})	7.50	16.5
Pb (mg kg^{-1})	4.80	26.05
Cd (mg kg^{-1})	0.35	0.45

contamination in the polluted fields in compare to the control field soils (Table 1). In polluted soils, Cr,Cu,Cd,Ni and Pb were 35.91,5.33,2.2,5.43 and 1.28 folds more, respectively than the control fields soil.The chromium in soil increased to 420.15mg Kg^{-1} in the polluted fields.The pattern of abundance of various metals in polluted soil were Cr>Pb>Cu>Ni>Cd. Overall there was no change in the profile of the soil type as it was sandy loam in both the cases with high humas content in the tannery polluted soils.

Metal accumulation in rice: The tannery polluted rice accumulated many folds heavy metals in comparison to the tubewell irrigated rice shoot, root and particularly in grains. The mean concentration of various elements in the rice plants showed that various metals were present significantly high in the roots as compared to shoots during flowering as well post flowering stage. There was many fold increase in the metal concentration in the rice plants growing in the polluted fields in comparison to the control fields (Table 2). The order of metal abundance in polluted rice crop wasCr>Cu>Pb>Ni>Cd. There are reports of hyper toxic metal accumulation in crops in different parts of world. Frost and Ketchum (2000); Bose and Bhattacharyya (2008) reported heavy metal accumulation in durum wheat. Zn uptake was observed in wheat (Santa-Mairia and Cogliatti, 1998). Rice cultivars and other crops are reported to accumulate Cd (Liu *et al.*, 2003; McBride, 2003). In Present investigations, in the consumable grains of polluted rice, the Cr,Cu,Cd,Ni and Pb were 1.75, 1.38, 1.39, 2.71 and 1.53 folds more, respectively than control. As per standard dietry intake given for the theses heavy metals, some of them (Cr,Cu and Ni) are more than the maximum allowed concentrations values. It is a great concern for health risk

Table 2. Concentration of metals in the rice plants in tubewell and tannery effluents irrigated fields

Metal	Pre-flowering stage		Harvest stage		
	Root	Shoot	Root	Shoot	Grain
Rice from control fields					
Cr	211.7	65.7	34.0	23.1	8.6
Cu	146.0	145.0	121.0	101.5	90.5
Cd	1.07	0.55	0.7	0.27	0.18
Ni	18.6	5.0	14.4	9.2	4.5
Pb	32.3	15.6	20.9	18.7	11.9
Rice from pollutes fields					
Cr	274.6	101.5	55.4	40.3	15.1
Cu	189.2	147.3	138.0	110.3	125.0
Cd	0.92	0.65	0.92	0.38	0.25
Ni	19.5	8.4	19.8	11.4	12.2
Pb	110.3	22.8	27.8	34.1	18.2

CD (0.05)			Root	Shoot			Grains
	A (Metals)	:	0.99	1.57	A(Metals)	:	0.81
	B (Stages)	:	1.58	2.48	B(Site)	:	0.51
	C (Site)	:	0.99	1.57			
Interaction	AxB	:	2.23	3.51	AXB	:	1.14
	BXC	:	2.23	3.51			
	AXC	:	1.41	NS			
	AXBXC	:	3.16	4.96			

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Table 3. Data on the biochemical estimations of rice plants collected from the tannery polluted fields and the tubewell irrigated fields.

Sites	Plant parts	Protein (mg g^{-1})	Carbohydrates (mg g^{-1})	Chlorophyll (mg g^{-1})
Preflowering				
Control	Leaves	0.34	0.45	50.53
Polluted	Leaves	0.19	0.33	26.90
Post Flowering				
Control	Leaves	0.62	0.75	43.3
Control	Grains	67.0	771.0	—
Polluted	Leaves	0.53	0.63	22.3
Polluted	Grains	54.0	742.0	—
CD (0.05)				
A (Stage of sampling)	:	0.03	0.11	0.41
B (Plant parts)	:	0.032	0.11	0.41
AXB (Interaction)	:	NS	NS	0.58

factors as this crop is one of staple food in India.

Biochemical analysis: There was significant decrease in the contents of these biochemicals like carbohydrates, proteins, chlorophyll in the grains and leaves harvested from rice plants from tannery polluted field as compared with control rice crops (Table 3). This ultimately effected the normal physiological functions of the crops, hinders normal growth and development including the photosynthetic capacity of crops and causing decease in the yields. Many reports are avaialble where it is seen that the metal toxicity have effected the biochemical profile of the crop plants. According to Prasad (1995), Cd effects chlorophyll, carotenoids and gas exchanges in the maize crops. Enzyme induction got effected due to heavy metal accumulation in plants (Van assche *et al.*,1988). According to Ewais (1997), Cd, Ni and Pb can effects the contents of chlorophyll, protein and growth of weeds. In present investigations, in the polluted grains the carbohydrates, proteins decreased to 742 (mg g^{-1}), 54 (mg g^{-1}) from 771 (mg g^{-1}),67 (mg g^{-1}), respectively, which was reported in the control rice grain. The chlorophyll content also decreased to 22.3 (mg g^{-1}) in the polluted rice leaves from 43.3 (mg g^{-1}), which was reported in the control rice leaves.

Due to the tannery pollution, the soils and rice crops are getting contaminated beyond the advisable limits. The degenerating biochemical profile due to metal toxicity is also a great concern. This all leads to great threat to human health and environment due to dietry intakes and also effecting the qualitative and quantitative crop production. The source of pollution should be checked and the polluted soils should be remediated for further use for cultivation.

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Nutrient Uptake, Root Density and Yield of Direct Seeded Rice-Wheat as Affected by Tillage Systems and N Levels

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Abstract: The maximum grain yield of rice was obtained with zero tillage with wheat straw at 100 kg N ha^{-1}, statistically at par with zero tillage without wheat straw at 125 kg N ha^{-1}. The 125 kg N ha^{-1} in zero tillage without wheat straw gave significantly higher yield than other N levels. The maximum grain yield was obtained in conventional tillage without wheat straw at 150 kg N ha^{-1}, which was significantly better than lower levels of N. The lowest weed number and dry matter was observed in zero tillage with wheat straw. The significantly more weed number and dry matter before and after spray was recorded at 150 kg N ha^{-1} than other N levels. The zero tillage with wheat straw recorded significantly higher uptake of N and P by grain at 100 kg N ha^{-1}. Conventional tillage with wheat straw at 150 kg N ha^{-1} registered higher potassium uptake by grains. Highest root density was recorded in zero tillage with wheat straw and zero tillage without wheat straw, but it slightly decreased under zero tillage without wheat straw than zero tillage with wheat straw. Maximum root density was observed with the application of 100 kg N ha^{-1}, but further increase in N did not increase the root density and 90 % of the roots were confined in top 0-15 cm soil layer. Tillage system had no significant effect on available N, P and K in soil at harvest. However, available N and K in the soil in all the treatments decreased but P improved from initial values. N, P and K in soil were significantly higher at 150 kg N ha^{-1} than other N levels. During *rabi* 2012-13, maximum grain yield of wheat was obtained in zero tillage with paddy straw at 150 kg N ha^{-1}.

Key Words: Grain yield, nitrogen levels, NPK uptake, planting methods, rice, root density, wheat straw

Rice-wheat is a dominant cropping system on fertile and irrigated alluvial soils of North-West India, particularly in Punjab and Haryana. In this region, conventional crop establishment practices in rice involves manual transplanting of rice in puddle soil, whereas, wheat is seeded in well puddle fine seedbed. These practices involve excessive tillage and hence, result not only in high-energy consumption but also in deterioration of soil structure. Puddling, a pre-requisite for rice transplanting, decreases the soil aggregates and pore size, thereby restricting germination and rooting of the succeeding crop (Giri *et al.*, 1993). In many parts of Punjab, water is increasingly becoming scarce. Poor quality irrigation systems and greater reliance on ground water have led to decline in water table. Rice requires continuous ponding of water for the first 15 days. This in turn leads to nutrient loss through leaching, besides causing high evapo-transpiration (ET) losses during hot summer. In view of the adverse effect of puddling, now-a-days the concept of no till and direct seeded rice are being popularized among farmers. Lal (1989) reported that the no tillage system mainly improve the soil biotic and soil physio-chemical environment but also increased the yield of different crops.

MATERIALS AND METHODS

Field experiment was conducted at Punjab Agricultural University, Ludhiana during *kharif* season of 2012-13 to see the influence of tillage and nitrogen on the productivity of rice-wheat cropping system. Treatments consisted of four tillage systems i.e., zero tillage with wheat straw (ZTWS), zero tillage without wheat straw (ZTWOS), conventional tillage with wheat straw (CTWS) and conventional tillage without wheat straw (CTWOS) and four levels of nitrogen as 0,100, 125 and 150 kg ha^{-1} were laid out in split plot design with three replications. In case of wheat, the treatments comprised as zero tillage with paddy straw (ZTPS), zero tillage without paddy straw (ZTPOS), conventional tillage with paddy straw (CTPS) and conventional tillage without paddy straw (CTPOS) and four levels of nitrogen as 0,100, 125 and 150 kg ha^{-1} were laid out in split plot design with three replications. The soil was loamy sand, neutral in reaction, low in organic carbon (0.17 %) and available N (214.8 kg ha^{-1}), medium in available P (19.5 kg ha^{-1}) and K (225.7 kg ha^{-1}) at sowing of direct seeded rice. The tillage systems were kept in main plots and nitrogen levels in sub plots. In *kharif*, crop was sown according to the treatments in the month of June using PR 115 variety of rice with recommended agronomic practices. The height of plant was measured from the base to the tip of last leaf till panicle emergence. After panicle emergence, height form the base to apex of the panicle was taken as height of the plant. Tillers were counted by using 50 cm x 50 cm quadrate from each plot. In each plot, fresh sample was taken from 25 cm area from row with the help of scale to ensure the increase in biomass production overtime. The collected plant biomass was first sun dried then oven dried at 62.5^{o} C till the constant

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weight, was expressed as q ha^{-1}. In *rabi*, wheat cv. PBW 550 was sown on November 14, 2012 using recommended practices.

RESULTS AND DISCUSSION

The maximum weed number before spray was recorded in CTWOS, which was significantly differed from other tillage systems. However, the lowest weed number was observed in ZTWS, it might be due to the mulching effect of wheat straw that reduces the germination of weeds. However, an increasing trend in weed number before and after spray was observed with an increase in N levels (Table 1). The maximum weed number before spray was in 150 kg N ha^{-1}. The weed dry matter before spray was significantly higher in CTWOS than other tillage systems. However, the lowest weed dry matter was recorded in ZTWS, it could be due to suppression of weed growth by wheat straw. It had also been observed that weed dry matter increased as the N increased and highest weed dry matter was recorded at 150 kg N ha^{-1}.

NPK uptake in rice: N uptake of grain was not influenced by tillage system. The different levels of N had significant effect on N uptake in grain. The N uptake in grain was significantly higher at 150 kg Nha^{-1} than control and 125 kg N ha^{-1}, but it was statistically at par with 100 kg N ha^{-1}(Table 2). The interaction effect of tillage systems and N levels was found significant for N uptake in grain. The maximum uptake of N was observed in grain in ZTWS at 100 kg N ha^{-1}, which was significantly better from other treatment combinations. Laroo *et al.* (2007) compared different levels of N and reported that the N uptake was more by rice grains as compared to straw; it might be due to higher concentration of N in grains as compared to straw.

The maximum phosphorus uptake in grain was recorded in ZTWS and was significantly varied from ZTWOS, CTWS and CTWOS tillage systems, however, uptake in straw in ZTWS and CTWS were at par. The phosphorus uptake in grain and straw was highest at 125 kg N ha^{-1}, and significantly differed from 0 and 150 kg N ha^{-1}, but was statistically at par with 100 kg N ha^{-1}. It was significantly higher with ZTWS at 100 kg N ha^{-1} than other treatment combinations. The application of 125 kg N ha^{-1} in CT and ZT with and without wheat straw gave significantly higher phosphorus uptake by grain than other N levels. The phosphorus uptake by grain was significantly higher in CTWOS at 150 kg N ha^{-1} than other N levels, whereas, CTWS at 150kg N ha^{-1} recorded higher phosphorus uptake in straw.

The potassium uptake in grain showed significant variation with tillage systems and N levels but non-significant variation in straw under different tillage system. Potassium uptake by grain in ZTWS was significantly higher than CTWS and CTWOS, but was statistically at par with ZTWOS. Potassium uptake by rice grain was higher at 125 kg N ha^{-1}, which was statistically at par with 100 and 150 kg N ha^{-1}, but significant better than control. The potassium uptake by grain in ZTWS at 100 kg Nha^{-1} was significantly higher than other treatment combinations. The application of 125 kg N ha^{-1} under ZTWOS was recorded significantly higher potassium uptake by grain than control and was statistically at par with 100 and 150 kg N ha^{-1}. Increase in potassium uptake in rice grain and straw might be due to increase in levels of N, which resulted in increased potassium concentration favorably. Similar results were observed by Laroo *et al.* (2007). Majumdar *et al.* (2005) observed that N

Table 1. Influence of tillage systems and nitrogen levels on weed number and dry matter before and after spray in direct seeded rice

Treatment	Weed number (m^2)		Weed dry matter(q ha^{-1})		N uptake by straw
	Before spray	After spray	Before spray	After spray	(kg ha^{-1})
Tillage system					
ZTWS	22.8	1.5	1.39	0.06	41.30
ZTWOS	24.4	1.8	1.38	0.06	37.63
CTWS	23.8	1.8	1.38	0.06	42.94
CTWOS	27.4	3.5	1.48	0.05	36.29
CD (0.05)	2.5	0.8	0.01	NS	2.27
Nitrogen level (kg ha^{-1})					
N_0	21.9	1.6	1.34	0.06	27.08
N_{100}	23.0	2.0	1.39	0.06	40.45
N_{125}	25.9	2.3	1.44	0.06	47.40
N_{150}	27.6	2.7	1.47	0.05	43.24
CD (0.05)	1.2	0.8	0.01	0.003	4.16

ZTWS- zero tillage with wheat straw, ZTWOS- zero tillage without wheat straw, CTWS- conventional tillage with wheat straw, CTWOS- conventional tillage without wheat straw

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Table 2. Effect of tillage systems and nitrogen levels on nitrogen, phosphorus and potassium uptake by grain* of direct seeded rice

Tillage system**	Nitrogen level (kg ha^{-1})				
	N_0	N_{100}	N_{125}	N_{150}	Mean
			Nitrogen uptake (kg ha^{-1})		
ZTWS	24.06	61.18	53.96	54.42	48.41
ZTWOS	24.83	48.92	51.29	49.79	43.71
CTWS	33.72	44.26	51.34	50.75	45.02
CTWOS	32.70	51.92	40.70	52.51	44.46
Mean	28.83	51.57	49.32	51.87	
CD (0.05)	Tillage system = NS; Nitrogen level = 2.21; Tillage system x Nitrogen level = 4.43				
			Phosphorus uptake (kg ha^{-1})		
ZTWS	7.91(5.25)	12.58(8.16)	10.42(6.30)	9.99(5.61)	10.22(6.33)
ZTWOS	7.40(4.47)	9.57(5.62)	10.13(7.43)	8.85(5.51)	8.99(5.76)
CTWS	7.89(5.59)	9.43(6.58)	10.48(7.59)	8.73(6.43)	9.13(6.52)
CTWOS	7.50(4.59)	8.05(6.13)	8.67(6.20)	10.04(7.41)	8.56(6.08)
Mean	7.67(4.95)	9.90(6.62)	9.92(6.88)	9.40(6.24)	
CD (0.05)	Tillage system = 0.13 (0.30); Nitrogen level = 0.16 (0.35); Tillage system x Nitrogen level = 0.33 (0.70)				
			Potassium uptake (kg ha^{-1})		
ZTWS	11.90 (95.92)	19.47(134.70)	14.74(128.33)	13.09(126.00)	14.80(121.24)
ZTWOS	12.18(92.23)	14.64(127.33)	16.17(135.33)	15.85(125.01)	14.71(119.98)
CTWS	12.49(101.53)	13.66(120.23)	14.52(128.00)	14.77(125.00)	13.86(118.69)
CTWOS	10.84(94.56)	13.44(120.13)	15.84(127.67)	15.73(129.61)	13.96(117.99)
Mean	11.85(96.06)	15.30(125.60)	15.32(129.83)	14.86(126.41)	
CD (0.05)	Tillage system = 0.75 (NS); Nitrogen level = 1.02 (3.77); Tillage system x Nitrogen level = 2.05 (7.55)				

* Straw uptake in parentheses

** For treatment details, check table 1

has complimentary effect on availability of other nutrients especially phosphorus and potassium. Enhancement in the uptake of N naturally results in enhancement in the uptake of the phosphorus and potassium.

NPK in soil: The available N, P and K in soil after the harvest of crop varied significantly with varying N level but did not vary under different tillage systems. It was observed that available N in the soil in all the treatments decreased from initial value (214.8 kg ha^{-1}). However, it was significantly higher at 150 kg N ha^{-1} than other N levels. The available P status in the soil was improved in all the treatments over the initial status (19.5 kg ha^{-1}) except control (Table 3). It continued to increase with increase in N fertilizer from 0 to 150 kg N ha^{-1}. The available K in the soil showed decrease in K than initial value of (225.7 kg ha^{-1}). The N levels had significant effect on available K in soil. Data indicated that the highest available K in soil at 150 kg N ha^{-1}, which was significantly varied from other N levels.

Root density: The data on root density from soil profile at panicle initiation was presented in table 4 revealed that highest root density was recorded in ZTWS and ZTWOS, but it slightly decreased under ZTWOS than ZTWS. This may be due to the availability of moisture for longer period in the presence of wheat straw, which resulted in better development of roots. However, root density was lowest under CTWOS. Root density increased with the increase in N up to highest level over the control. However, the maximum root density was observed with the application of 100 kg N ha^{-1}, but further increase in N did not increase the root density. It was also observed that 90 per cent of the roots were confined in top 0-15 cm soil layer, and observed reduction in root density after this layer.

Grain and straw yield rice: The tillage systems had significant influence on the grain yield of rice. The grain yield observed in ZTWS significantly higher than CTWS and CTWOS, but it was statistically at par with ZTWOS. Similar results were obtained by Bhattacharyya *et al.* (2008). With the increase in N levels, the grain yield increased significantly and maximum grain yield was obtained with 125 kg N ha^{-1}, and was significantly differed from control and 150 kg N ha^{-1}, but statistically at par with 100 kg N ha^{-1}. It might be due to more attack of insect pest like leaf folder, brown leaf spot and sheath blight at higher dose of N (150kg N ha^{-1}). The beneficial effect of N application on various yield attributing characters led to increased grain yield with increasing levels of N. Similar results were reported by Rammohan *et al.* (2002).

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Table 3. Influence of tillage systems and nitrogen levels on available nitrogen, phosphorus and potassium (kg ha^{-1}) in soil

Treatment*	Available N	Available P	Available K	Bulk density (g cm^{-3})
Tillage system				
ZTWS	180.18	22.37	159.26	1.42
ZTWOS	176.94	21.26	156.16	1.44
CTWS	179.17	21.72	157.65	1.44
CTWOS	176.15	20.98	155.74	1.46
CD (0.05)	NS	NS	NS	NS
Nitrogen level (kg ha^{-1})				
N_0	155.77	19.16	137.81	1.44
N_{100}	173.41	21.64	157.34	1.45
N_{125}	183.95	22.34	164.58	1.46
N_{150}	199.31	23.18	169.07	1.45
CD (0.05)	5.30	0.84	2.46	NS

*See table 1 for treatment details

The straw yield was significantly influenced by tillage systems and followed the trend of grain yield. The straw yield increased significantly up to 125 kg N ha^{-1} thereafter decreased but at par with 150 kg N ha^{-1} (Table 5). The interaction between tillage system and nitrogen levels was significant. The straw yield registered maximum in CTWS at 125 kg N ha^{-1} than other treatment combinations, but it was statistically at par with ZTWS at 100 kg N ha^{-1}, ZTWS, ZTWOS and CTWOS at 125 kg N ha^{-1} and ZTWS, CTWS and CTWOS at 150 kg N ha^{-1}.

Grain yield of wheat: The grain yield of wheat was significantly influenced by tillage systems. The grain yield of wheat was significantly higher in ZTPS as compared to ZTPOS, CTPS (Table 6). Higher wheat yield was also obtained under zero tillage over the conventional tillage by Singh *et al.* (2010); Singh *et al.* (2011); Kaushal *et al.* (2012a,b); Singh *et al.* (2012a,b,c). However, CTPS produced considerable higher grain yield than CTPOS. Similarly, ZTPOS produced significantly less grain yield than ZTPS. The results are inconformity with the findings of Kumar *et al.* (2004). They found that incorporation and retention of rice residue on soil surface in succeeding wheat field remarkably enhanced the grain yield over residue removal. With increase in N, the yield of wheat also increased and the highest grain yield was obtained with the application of 150 kg N ha^{-1}, which significantly differed from other N levels. Grain yields were increased significantly with increasing increment of N up to 150 kg N ha^{-1} (Yadav *et al.*, 2005; Kaushal *et al.*, 2012a,b; Singh and Kaur, 2012).

On the basis of above discussion, it could be concluded that rice can be sown with ZTWS at 100 kg N ha^{-1} and ZTWOS at 125 kg N ha^{-1} for higher grain yield. However, wheat should be sown with ZTPS and ZTPOS at 150 kg N ha^{-1} for higher productivity.

Table 4. Influence of tillage systems and nitrogen levels on root density (g m^{-3}) at panicle initiation

Treatment*	Soil profile depth (cm)			
	0-15	15-30	30-60	60-90
Tillage system				
ZTWS	2624.7	250.5	46.3	9.5
ZTWOS	2548.1	232.6	36.4	9.0
CTWS	2494.3	221.5	33.5	8.6
CTWOS	2445.2	219.4	29.5	8.3
Nitrogen (kg ha^{-1})				
N_0	2468.8	220.2	30.0	8.2
N_{100}	2572.5	239.9	42.7	9.2
N_{125}	2566.8	237.1	41.6	9.1
N_{150}	2504.2	226.8	31.4	8.9

*See Table 1 for treatment detals

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Table 5. Effect of tillage systems and nitrogen levels on grain and straw yields (q ha^{-1})of direct seeded rice

Tillage system*	Nitrogen level (kg ha^{-1})				
	N_0	N_{100}	N_{125}	N_{150}	Mean
			Grain yield (q ha^{-1})		
ZTWS	32.2	52.4	47.5	45.2	44.3
ZTWOS	31.7	46.9	49.8	44.7	43.3
CTWS	35.4	43.1	46.6	44.6	42.4
CTWOS	32.9	42.3	43.5	46.5	41.3
Mean	33.1	46.2	46.8	45.2	
CD (0.05)	Tillage system = 1.5; Nitrogen level = 1.4; Tillage system x Nitrogen level = 2.8				
			Straw yield (q ha^{-1})		
ZTWS	50.9	70.8	66.8	67.7	64.1
ZTWOS	47.7	61.2	69.1	61.8	59.9
CTWS	57.2	61.7	72.4	70.4	65.4
CTWOS	52.8	61.3	68.2	70.6	63.2
Mean	52.1	63.8	69.1	67.6	
CD (0.05)	Tillage system = 3.1; Nitrogen level = 3.3; Tillage system x Nitrogen level = 6.7				

*See table 1 for treatment details

Table 6. Interaction effect of tillage systems and levels of nitrogen on grain yield (q ha^{-1}) of zero-till wheat

Tillage system*	Nitrogen (kg ha^{-1})				
	N_0	N_{100}	N_{125}	N_{150}	Mean
ZTPS	28.3	45.0	48.5	55.2	44.3
ZTPOS	23.7	37.6	41.6	54.5	39.4
CTPS	29.5	36.2	44.2	51.4	40.3
CTPOS	25.1	38.2	43.4	42.8	37.4
Mean	26.7	39.3	44.4	51.0	
CD (0.05)	Tillage system = 3.4; Nitrogen level = 1.3; Tillage system x Nitrogen level = 2.5				

*See table 1 for treatment details

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Response of Knolkhol cv. Early White Vienna to Drip Irrigation and Fertigation in Kashmir Region

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Abstract: The experiment consisted of sixteen treatment combinations and replicated four times in a factorial randomized block design. The treatments include four levels of irrigation and fertilizer application. The growth and yield characteristics of knolkhol cv. Early White Vienna were significantly influenced by drip irrigation and fertigation levels. However, the treatment combination of 80% ET through drip (40.04 cm) + 80% recommended NPK (100:48:64 kg ha^{-1}) through fertigation proved significantly superior over rest of the treatments in terms of growth and yield contributing characteristics with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that of surface irrigation and manual fertilizer application. It was further concluded that the treatment combination of 60% ET through drip + 80% recommended NPK through fertigation recorded maximum water use efficacy (8.92 q ha^{-1} cm), whereas, the maximum fertilizer use efficiency (NUE-3.61 q kg^{-1} N, PUE-7.52 q kg^{-1} P and KUE-5.64 q kg^{-1} K) was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation.

Key Words: Drip irrigation, fertigation, water use efficiency, fertilizer use efficiency, knolkhol

Knolkhol (*Brassica oleracea* cv. *gongylodes* L.) is a temperate vegetable and very popular in Kashmir region. Although Kashmir is rich in its water resources and there are several methods of providing irrigation to vegetable crops, yet drip irrigation is very useful for the region, because most of the orchard crops exist in the uplands where the scarcity of water is felt largely by the farmers throughout the year. Drip irrigation can be very effectively utilized in such land situations of the region. The research work on adoption of drip irrigation and fertigation practices in different vegetable crops revealed the efficiency of the system in reducing the water and fertilizer requirement with increased yield. However, very little literature is available pertaining to performance of knolkhol under drip system. The results of the present study revealed a significant and positive response of knolkhol under drip irrigation and fertigation system. In view of importance of drip irrigation system and need for its diversification, the present study was conducted to assess the performance of knolkhol for increased yield and effective use of irrigation water and fertilizers for Kashmir region.

MATERIAL AND METHODS

The present investigation was carried out at the Experimental Farm of Division of Olericulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir, Shalimar, Srinagar (J&K). Factorial randomized block design was followed with sixteen treatment combinations and four replications. The treatments comprised of four levels of irrigation *viz.* 100%, 80% & 60% ET through drip and 100% surface irrigation; and 4 levels of fertilizers application such as 100%, 80% & 60% recommended NPK through fertigation and 100% recommended NPK through traditional approach. Surface irrigation and manual application of fertilizers were treated as control. The volume of water required under drip irrigation system was computed using following equation: V = [DE x CF x AA x PC]/IE

Where, V= Volume of water required (l $plant^{-1}$ day^{-1}), DE = Daily pan evaporation (mm), CF = Crop factor, AA = Area allotted per plant (m^2), PC = Pan coefficient and IE = Irrigation efficiency as a decimal. The crop factor (CF) is related to relative water demand to crop growth stages and the respective CF value for knolkhol was taken as 0.30, 0.60, 0.95 and 0.80, respectively for initial, development, mid-season and during late-season stage. The pan factor value was 0.75 as suggested for USDA class-A pan. The area allotted per plant was 0.12 m^2.

Twenty-two days old seedlings of knolkhol cv. Early White Vienna were transplanted on 22nd September 2007 with 6 rows per plot keeping row to row and plant to plant distance of 30 and 40 cm, respectively. Drip system was laid out parallel to the crop rows and each lateral with emitter distance at 40 cm and 2.2 l h^{-1} discharge rate. The amount of water actually applied by way of drip irrigation was based on climatologically approach and pan evapo-transpiration. Irrigation was scheduled on alternate day in case of drip irrigation and need based surface irrigation was applied.

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Fertigation with RFD 125:60:80 kg NPK ha^{-1} was given according to the treatments in eight split doses at ten days interval beginning 10 days after transplanting. However, in case of manual fertilizer application, half dose of nitrogen (as urea) and full doses of phosphorus (as SSP) and potassium (as MOP) were applied as basal doses while the remaining half dose of nitrogen was applied at 20 and 40 days after transplanting as top dressing. All the other packages and practices were adopted as recommended for the region (Anonymous 2005). Observations were recorded for various growth, yield and quality traits. Volumetric method was used for calculating the uniformity coefficient of drip irrigation system (Raina *et al.*, 1999). The water use efficiency was computed by dividing yield (q ha^{-1}) with total water applied (cm) including effective rainfall. The fertilizer use efficiency was worked out separately for N (NUE-nitrogen use efficiency), P (PUE-phosphorus use efficiency) and K (KUE-potassium use efficiency) by dividing total yield (q ha^{-1}) with total fertilizer applied (kg ha^{-1}).

RESULTS AND DISCUSSION

In order to check the efficiency of drip irrigation system, uniformity coefficient (UC) of drip irrigation system was worked out and was found to be 93.8%. The high value of UC indicates the excellent performance of the system in supplying water uniformly throughout the laterals.

Drip irrigation levels significantly influenced the growth and yield characteristics (Table 1). Drip irrigation at 80% ET proved significantly superior over other treatments by recording the maximum plant height (30.30 cm), no. of leaves plant^{-1} (14.09), plant spread (41.19 cm), leaf length (27.90 cm), leaf breadth (10.04 cm), knob length (6.11 cm), knob diameter (7.35 cm), root length (15.71 cm), root diameter (1.09 cm), average root weight (16.73 g), average leaf weight (11.20 g), average knob weight (328.09 g), gross weight per plant (486.1 g), knob weight (17.25 kg plot^{-1}) and knob yield (266.31 q ha^{-1}), whereas, the surface irrigation noticed minimum values for these mentioned characters with lowest yield (185.56 q ha^{-1}). The improved growth and yield of knolkhol under drip irrigation might be due to the regular availability of water around the root zone at very low moisture tension, reduced runoff and leaching losses, hence available fully to plants.

The response of various fertigation levels in knolknol cv. Early White Vienna showed that all the fertigation levels exhibited significant improvement in various growth and yield characters in comparison to manual fertilizer application (Table 2). However 80% recommended NPK through fertigation produced maximum values for plant height (28.72 cm), no. of leaves/plant (13.48), plant spread (42.02 cm), leaf length (26.62 cm), knob length (5.62 cm), knob diameter (6.75 cm), average knob weight (305.35 g), grass weight plant^{-1} (426.0 g), knob weight plot^{-1} (16.02 kg) and knob yield (248.26 q ha^{-1}) whereas 100% recommended NPK through fertigation recorded maximum leaf breadth (9.71 cm), root length (15.53 cm), root diameter (1.03 cm), average root weight (15.84 g) and average leaf weight (10.60 g). The minimum knob yield (207.82 q ha^{-1}) was found with the manual fertilizer application. Fertigation allows more controllable application of nutrients during the crop growing season and also restricts leaching losses of nutrients as compared to other methods of fertilizers application including traditional broadcasting method, and hence realizes higher yield. Increased growth and yield of cabbage, lettuce and cauliflower under fertigation system was earlier reported by Titular (1995).

Combined drip irrigation and fertigation, supply and maintain an optimum level of both moisture and nutrients within the root zone, with irrigation water acting as a vehicle for the nutrients required by the crop. The results of the present study confirm the superiority of combined effect of drip irrigation and fertigation over their individual effects in knolkhol (Table 3). The treatment combination of 80% ET through drip + 80% recommended NPK was found best among all other treatment combinations with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that control. The same treatment combination also recorded maximum plant height, no. of leaves plant^{-1}, plant spread, knob length, diameter and weight, gross weight plant^{-1}. However, leaf length, leaf breadth, root length, root diameter, average root weight and average leaf weight registered maximum values with the treatment combination of 80% ET through drip + 100% recommended NPK through fertigation. Our findings are in accordance with the findings of Rubeiz *et al.* (1989) and Burnette *et al.* (1993) in cabbage and broccoli, Hochmuth *et al.* (1994) in lettuce, Thompson *et al.* (2000) in cauliflower and Ristimaki *et al.* (2000) in cabbage.

Water use efficiency: Results obtained revealed that drip irrigation substantially decreased the consumptive use of water in knolkhol in comparison with surface irrigation (Table 1 and Table 4). Drip irrigation at 100%, 80% and 60% ET consumed 50.05, 40.04 and 30.03 cm ha^{-1} water throughout the cropping season; while the surface irrigated plots consumed 66.2 cm ha^{-1} water and saving of irrigation water in the tune of 24.3%, 39.5% and 54.6%, respectively through drip irrigation over surface irrigation, leading to a significant increase in water use efficiency. However, the maximum water use efficiency (8.07 q ha^{-1} cm) was observed with 60% ET though drip followed by 80% ET through drip (6.65 q ha^{-1} cm) and 100% ET through drip (4.58 q ha^{-1} cm),

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Table 1. Effect of drip irrigation on growth, yield and water use efficiency in knolkhol cv. Early White Vienna

Treatment*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root weight (g)	Av. leaf weight (g)	Av. knob weight (g)	Gross weight plant^{-1} (g)	Knob weight. plot^{-1} (kg)	Knob yield (q ha^{-1})	Water applied (cm)	WUE (q ha^{-1} cm)
I_1	26.58	11.75	39.29	27.15	9.53	4.88	5.97	15.20	0.94	15.74	10.63	273.93	356.9	14.79	229.37	50.05	4.58
I_2	30.30	14.09	41.19	27.90	10.04	6.11	7.35	15.71	1.09	16.73	11.20	328.09	486.1	17.25	266.31	40.04	6.65
I_3	27.83	13.15	40.48	24.05	8.43	5.24	6.47	13.47	0.83	12.44	8.60	290.84	401.0	15.70	242.36	30.03	8.07
I_4	22.81	10.06	35.79	21.99	7.48	3.75	4.74	12.55	0.75	10.02	7.46	222.77	278.2	12.02	185.56	66.2	2.80
CD (0.05)	1.67	0.89	1.50	1.40	0.68	0.31	0.40	0.78	0.01	0.74	0.72	29.90	13.52	1.61	24.92	-	-

*I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation

Table 2. Effect of fertigation on growth, yield and fertilizer use efficiency in knolkhol cv. Early White Vienna

Treatment*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob dia-meter (cm)	Root length (cm)	Root dia-meter (cm)	Av. root weight (g)	Av. leaf weight (g)	Av. knob weight (g)	Gross weight plant^{-1} (g)	Knob weight plot^{-1} (kg)	Knob yield (q ha^{-1})	NUE (q kg^{-1} N)	PUE (qkg^{-1} P)	KUE (qkg^{-1} K)
F_1	25.90	11.88	39.43	27.20	9.71	4.86	5.89	15.53	1.03	15.84	10.60	272.04	371.1	14.68	226.69	1.81	3.77	2.83
F_2	28.72	13.48	42.02	26.62	9.34	5.62	6.75	14.99	0.97	15.20	10.27	305.35	426.0	16.02	248.26	2.48	5.17	3.87
F_3	27.85	13.03	41.12	24.86	8.60	5.28	6.33	13.90	0.85	13.29	9.19	288.93	399.5	15.60	240.83	3.21	6.68	5.01
F_4	25.05	10.66	35.19	22.40	7.82	4.22	5.56	12.50	0.77	10.60	7.83	249.30	325.5	13.46	207.82	1.66	3.46	2.59
CD (0.05)	1.67	0.89	1.50	1.40	0.68	0.31	0.40	0.78	0.01	0.74	0.72	29.90	13.52	1.61	24.92	-	-	-

*F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

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Table 3. *Effect of drip irrigation and fertigation on growth and yield characters of knolkhol cv. Early White Vienna*

Treatment combination*	Plant height (cm)	No. of leaves plant^{-1}	Plant spread (cm)	Leaf length (cm)	Leaf breadth (cm)	Knob length (cm)	Knob diameter (cm)	Root length (cm)	Root diameter (cm)	Av. root wt. (g)	Av. leaf wt. (g)	Av. knob wt. (g)	Gross weight plant^{-1} (g)	Knob weight plot^{-1} (kg)	Knob yield (qha^{-1})
I_1F_1	25.57	11.73	39.31	28.80	10.13	4.57	5.67	16.07	1.03	17.50	11.70	267.22	334.40	14.43	222.77
I_1F_2	28.87	13.33	41.98	28.07	9.80	5.67	6.67	15.73	0.99	16.87	11.50	293.51	422.90	15.85	244.68
I_1F_3	27.20	12.47	40.17	26.97	9.33	5.07	6.05	15.17	0.94	15.60	10.60	285.74	366.80	15.43	238.17
I_1F_4	24.70	9.47	35.79	24.77	8.87	4.23	5.00	13.83	0.83	13.00	8.73	249.25	303.80	13.46	207.87
I_2F_1	29.07	13.27	41.67	29.77	11.10	6.13	7.45	16.93	1.37	18.50	12.50	322.70	504.00	17.42	268.80
I_2F_2	32.20	15.20	44.77	29.30	10.47	6.60	7.90	16.53	1.18	18.33	12.00	377.80	537.00	18.24	281.50
I_2F_3	31.40	14.97	43.97	27.33	9.67	6.33	7.63	15.33	0.97	16.30	11.20	325.18	510.40	17.56	270.98
I_2F_4	28.53	12.93	38.46	25.23	8.93	5.40	6.03	14.07	0.89	13.80	9.10	292.70	393.00	15.81	243.99
I_3F_1	26.33	12.07	39.82	26.10	9.43	4.90	5.87	14.87	0.93	14.87	10.00	267.90	357.30	14.46	223.13
I_3F_2	29.93	14.20	43.19	25.83	9.20	6.05	7.10	14.50	0.90	14.50	9.70	321.29	445.90	17.35	267.87
I_3F_3	29.33	13.77	42.67	22.90	7.77	5.80	6.83	12.87	0.79	12.00	7.73	319.07	430.30	17.23	265.99
I_3F_4	25.73	12.60	36.37	21.40	7.33	4.23	5.10	11.67	0.70	8.40	7.00	255.10	370.80	13.77	212.49
I_4F_1	22.63	10.47	36.99	24.17	8.20	3.87	4.59	14.27	0.82	12.50	8.23	230.37	289.00	12.44	192.07
I_4F_2	23.90	11.20	38.22	23.30	7.90	4.17	5.33	13.20	0.81	11.13	7.90	234.81	298.50	12.68	195.80
I_4F_3	23.47	10.93	37.80	22.27	7.67	3.95	4.83	12.27	0.73	9.27	7.23	225.74	290.80	12.19	188.23
I_4F_4	21.27	7.67	30.33	18.23	6.17	3.03	4.23	10.47	0.67	7.20	6.50	200.18	234.50	10.81	166.97
CD(0.05)	3.35	1.79	3.01	2.81	1.36	0.63	0.80	1.57	0.02	1.49	1.45	59.8	27.49	3.23	49.84

*I_1 = 100% ET through drip irrigation; I_2 = 80% ET through drip irrigation; I_3 = 60% ET through drip irrigation; I_4 = 100% Surface irrigation

F_1 = 100% RFD through fertigation; F_2 = 80% RFD through fertigation; F_3 = 60% RFD through fertigation; F_4 = 100% RFD through manual application

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Table 4. Effect of drip irrigation and fertigation on yield enhancement, water and fertilizer use efficiency in knolkhol cv. Early White Vienna

Treatment combination*	Yield (q ha^{-1})	Increase in yield (%)	Water applied (cm)	Water saving (%)	WUE (q ha^{-1} cm)	Fertilizer applied (NPK kg ha^{-1})	Fertilizer saving (%)	Fertilizer use efficiency		
								NUE (q kg^{-1} N)	PUE (q kg^{-1} P)	KUE (q kg^{-1} K)
I_1F_1	222.77	33.3	50.05	24.3	4.45	125:60:80	-	1.78	3.71	2.78
I_1F_2	244.68	46.5	50.05	24.3	4.96	100:48:64	20	2.48	5.18	3.88
I_1F_3	238.17	42.6	50.05	24.3	4.75	75:36:48	40	3.17	6.61	4.96
I_1F_4	207.87	24.4	50.05	24.3	4.15	125:60:80	-	1.66	3.46	2.59
I_2F_1	268.80	60.9	40.04	39.5	6.17	125:60:80	-	2.15	4.48	3.36
I_2F_2	281.50	68.5	40.04	39.5	7.03	100:48:64	20	2.81	5.86	4.39
I_2F_3	270.98	62.2	40.04	39.5	6.76	75:36:48	40	3.61	7.52	5.64
I_2F_4	243.99	46.1	40.04	39.5	6.09	125:60:80	-	1.95	4.06	3.04
I_3F_1	223.13	39.6	30.03	54.6	7.43	125:60:80	-	1.78	3.71	2.78
I_3F_2	267.87	60.4	30.03	54.6	8.92	100:48:64	20	2.67	5.58	4.18
I_3F_3	265.99	59.3	30.03	54.6	8.85	75:36:48	40	3.54	7.38	5.54
I_3F_4	212.49	27.2	30.03	54.6	7.07	125:60:80	-	1.69	3.54	2.65
I_4F_1	192.07	15.0	66.20	-	2.90	125:60:80	-	1.53	3.20	2.40
I_4F_2	195.80	17.2	66.20	-	2.95	100:48:64	20	1.95	4.07	3.05
I_4F_3	188.23	12.7	66.20	-	2.84	75:36:48	40	2.50	5.22	3.92
I_4F_4	166.97	-	66.20	-	2.52	125:60:80	-	1.33	2.78	2.08

* See table 3 for details

whereas, the lowest water use efficiency (2.80 q ha^{-1} cm) was found with surface irrigation. More benefits of water use efficiency were observed with the combined application of drip irrigation and fertigation. Among various treatment combinations, 60% ET through drip + 80% recommend NPK though fertigation recorded maximum water use efficiency (8.92 q ha^{-1} cm). Since the rate of water losses through evaporation, percolation and leaching was much lower under drip irrigation, hence water use efficiency was higher as compared to surface irrigation. These results are in agreement with the earlier findings of Sharanappa *et al.* (2000), Thompson *et al.* (2000), Anil *et al.* (2001) and Gupta *et al.* (2010).

Fertilizer use efficiency: Among different fertigation levels, fertigation with 60% recommended NPK saved a considerable amount (40%) of fertilizers with maximum fertilizer use efficiency (NUE-3.21 q kg^{-1} N, PUE-6.68q kg^{-1} P and KUE-5.01 q kg^{-1} K) (Table 2 and 4). In case of combined application of drip irrigation and fertigation, the treatment combination of 80% ET through drip + 60 % recommended NPK through fertigation recorded the maximum fertilizer use efficiency (NUE-3.61 q kg^{-1} N, PUE-7.52 q kg^{-1} P and KUE-5.64 q kg^{-1} K). Fertilizer use efficiency under drip irrigation and fertigation system might have increased due to higher and readily availability, the efficient use of nutrients at various stages of crop growth and practically no leaching of nutrients in the form of runoff. Similar benefits of fertilizers use efficiency were also reported by Everaarts (1993) in broccoli, Kaniszewski *et al.* (1999) in white cabbage, Thompson *et al.* (2000) in cauliflower and Gupta *et al.* (2009) in sprouting broccoli.

It was concluded that the treatment combination of 80% ET through drip + 80% recommended NPK through fertigation proved significantly superior over rest of the treatments in terms of growth and yield contributing characteristics with maximum knob yield (281.50 q ha^{-1}), which was found 68.5% higher than that of surface irrigation and manual fertilizer application (166.97 q ha^{-1}). The treatment combination of 60% ET through drip + 80% recommended NPK through fertigation recorded maximum water use efficacy (8.92 q ha^{-1} cm), whereas, the maximum fertilizer use efficiency was observed with the treatment combination of 80% ET through drip + 60% recommended NPK through fertigation.

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Studies on Nest Architecture and Pollination Potential of Bumble Bee (*Bombus haemorrhoidalis*)

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Abstract: Pollination potential of bumble bee *Bombus haemorrhoidalis* Smith was studied along with their rearing. Bumble bee queens were trapped from different flora during spring. During 2009-2010, eleven queens raised their progeny successfully in confinement (incubator) and three colonies raised their progeny for the first time under room temperature (control). Domiciles 16x12x10cm and 15x12x8cm with different nesting materials (cotton, moss and filter paper with bottle lid) were accepted to the level of 75 per cent, however, the per cent acceptance was 41.66 for the domiciles having 25x20x15cm dimensions. Hoarding cages were not accepted by the queens. The average time for wax secretion and development from egg to adult was 6.7 days and 26.21 days. Reared bumble bee colonies were successfully used for pollinating cucumber grown under polyhouse in increased fruit set, healthy fruits, fruit length, diameter, weight, seed number and weight with reduction in crooked fruits. The cost benefit ratio was 1:2.02 and an increase of 22 per cent in the total returns from bumble bee pollinated crop over non-pollinated crop.

Key Words **:** Bumble bees, nest architecture, pollination, cucumber, protected conditions

In horticulture and agriculture, honey bees are mainly utilized for the pollination of crops. Over the last few decades, the trend of cultivating crops has shifted towards protected cultivation. Besides, due to changing climatic conditions and increased *Varroa* mite infestation, the apiculture industry received a setback. Under such critical situations, it becomes obvious to take into account the immense role and utility of native pollinators in pollinating various economically important crops. Bees can be used for the pollination of crops under protected conditions. Bumble bees are found to be the most efficient and reliable pollinators under protected conditions and work well under adverse conditions of temperature and cool weather. It is also valuable in buzz pollinating the crops such as tomato (Corbet *et al.*, 1982; Erikson and Buchmann, 1983). Bumble bees lives either underground in pre-existing small, mammal nests or above ground in dry vegetation comprising of thick dry leaves and wooden twigs. Several attempts have been made earlier by different workers to raise bumble bee colonies in captivity by artificial methods and utilize them for pollination in both open and protected conditions (Plowright, 1996). But in India, no attempts were made till first decade of this century.

Attempts to rear bumble bees were started in 2002 and were successfully reared in captivity during 2005-2008 (Kashyap, 2008). To avoid several problems such as increased humidity and moisture, several advances have been made. Techniques have been developed to rear bumble bees for pollination of high value crops under protected conditions to increase productivity (Berezin and Beiko, 2000; Anonymous, 2009). As the Indian agriculture is shifting towards protected cultivation to make available the crops throughout the year with quality produce, the present study was formulated to know the pollination efficiency of bumble bee with the refinement of its rearing technology for the successful domestication of this native pollinator, which is a highly commercial pollinator under protected cultivation conditions in the Eastern and Western countries.

MATERIALS AND METHODS

The studies were carried out in the Department of Entomology and Apiculture (February to June and August to October in 2009-2010) and Experimental Farm of the Department of Vegetable Science (June to August in 2009-2010); Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.

Natural nest architecture studies: These studies were conducted at Sarot, Jubbal (2300 meters above mean sea level, 31.1094667ºN; 77.662996ºE) and Nauni (1250 metres above mean sea level) at a longitude of 77º 11' 30" E and a latitude of 30º 52' 30 N". Nests of bumble bees were located at different altitudes by listening to the buzzing sounds of the bumble bees in the forest and field areas (cultivated and barren lands). The bumble bee nests were observed regularly till the activity ceased. The nests were, then dug out and brought to the laboratory for studying the composition, structure, nesting materials and type of cells in the nests. The outer covering of the composite nest i.e. nesting material was isolated from the brood area to know the composition of nests. The nests were evaluated to

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determine the variations in the shape of the nests collected from different altitudes. Different cells of bumble bee nests were separated to study the dimensions of different cells (queen cells, worker cells and honey-pots) with digital Vernier calliper. The average of cells was taken to know the difference in the dimensions of different cell types.

Refinement of bumble bee rearing technique: Four types of boxes each with three different nesting materials having three replications for each box were taken. The domiciles had different dimensions with different nesting materials. The domiciles were made up of ply-wood, divided into two equal chambers viz., brood chamber and defecating chamber and had a sliding glass at the top to observe the nest construction and brood activity without disturbing the queen. The glasses were covered with inner covers from above to avoid the entry of direct light. The base of the defecating chamber was made sliding and perforated for easy removal of debris from the colony and to maintain hygiene in the nest along with removing excess moisture to the outside. Two holes were provided in the side wall for proper ventilation. The dimensions of different domiciles were 15x12x 8cm, 16x12x10cm and 25x20x15cm. Hoarding cages had dimensions of 33x20x10cm. All cages had a small hole in the centre, which provided a free space for the queen and workers for movement between brood and defecating chambers.

With the onset of spring, the bumble bee queens were collected in the early morning and evening during foraging for pollen and nectar with the help of insect collecting nylon net. The queens were brought to the laboratory in plastic vials having perforated lids and were placed in refined domiciles with proper feeding provisions. Spring captured bumble bee queens were put in the wooden domiciles having different nesting materials (moss, thermo-cole, cotton, filter paper and sponge sheets) and kept in controlled conditions in the incubator at 26.9°C temperature and 65 per cent relative humidity. Queens were fed with honey bee-collected pollen and 50 per cent sucrose solution. Similarly, queens were kept at room temperature to know the success of rearing the bumble bees under room temperature ranging between 32-36°C and 50-60 per cent relative humidity. These queens were fed with both 50 per cent sugar/sucrose solution and grinded or pollen pellets. Time taken by the queens for wax secretion and emergence of workers was recorded.

Utilization of bumble bee under protected conditions for the pollination of cucumber: For pollination studies under protected conditions, the experiment was conducted in a 200m² plastic greenhouse using randomized block design. Total 32 blocks were made out of which 24 blocks were exposed to bumble bee pollination while eight blocks were left out for control treatment. The cucumber (Punjab Naveen) crop was sown in the first week of April. In each block, twelve plants were planted, thus making a total of 384 plants in three replications. An insect proof net was placed between the experimental and control plots to avoid pollination in control plots. Cucumber plants were also planted in open conditions during the last week of February in randomized block design to know the effect of natural pollination on cucumber productivity under open conditions. A total of sixty blocks were made and in each block twelve plants were planted. The plants came to bloom during the month of June.

Artificially reared bumble bee colony was introduced in blooming cucumber crop (with 5-10% flowers opened) in the polyhouse by placing it inside a big box (30x30x30cm) to which a plastic tube was attached, which served as a passage for entry and exit for bumble bee foragers. Foraging activity of bumble bees was recorded on cucumber grown inside polyhouse from early morning hours (0600h) till late evening (1800h) at two hour interval for 20 days continuously. For comparative studies, similar data were recorded under open conditions.

For studying the crop productivity, the female flowers per vine were pre-counted. Ten plants from each treatment viz., bumble bee pollinated, control and open pollinated were selected randomly. The fruit set on these plants were then recorded and total yield was calculated on fruit set basis. The per cent healthy fruits crooked fruits were calculated by counting the number of healthy/crooked fruits from the total fruit set. Fruit length, fruit diameter and fruit weight were measured using scale, digital Vernier calliper and digital weighing balance, respectively.

The average of 10 fruits was taken for each pollination treatment. The seeds from each fruit were removed and kept separately in water for 24 hours. After washing, the seeds were dried by keeping them in temperature controlled chambers for 24 hours, and then counted. One thousand dried seeds from each treatment were taken separately in the petriplate and weighed. Per cent increase in the fruit set, healthy fruits, crooked fruits, length, diameter, weight, number of seeds, weight of 1000 seeds was calculated as per cent increase in bumble bee pollinated cucumbers over control.

Cost-benefit ratio was worked out for cucumber grown under polyhouse conditions and the per cent increase in total returns was calculated for increase in the cucumber productivity and production in bumble bee pollinated plants over control.

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RESULTS AND DISCUSSION

Nest architecture: The nest located at Sarot, Jubbal (Nest 1) was dug out in the month of November when the activity of bumble bees ceased before snowfall. The nest was built inside the abandoned, old rodent burrow having one small opening. Nest was attached to the roots of an adjoining apple tree. An involucrum made of waxy substance was found covering the nest from top. Some pine needles were found in the tunnel and the tunnel end, leading into a wide cavity where the brood having different scattered cells were found. The nest was circular with diameter and height of 12.56 and 6.8cm (Table 1). The nest located at Nauni (Nest 2) was dug out in the month of December. It was located in the abandoned nest of some rodent beneath heap of big stones with broad opening and was interwoven with long grass. Single entrance of nest was found bifurcated into a number of tunnels. The nest was found at a depth of 90cm and the length of the tunnel was found to be 150cm. Nest was rested on the flat surface and was attached to roots of nearby tree. It was built with interwoven dry grass, leaves, small wooden twigs and some plastic material. The involucrum of wax covered the nest. The nest had three entrances from the involucrum. The diameter and height of the nest were found to be 17.25 and 7cm, respectively. Beneath the involucrum the worker, queen and honey pot cells were observed. The brood filled most of the cavity beneath the nest canopy. The surface of nest was completely dry and free of mold. The nest contained both sealed and unsealed brood. The brood batches were arranged in circular manner. Some beetles were found in the colony at Nauni and were identified as *Antherophagus* sp., which was found to be pollen feeder. The dimensions of the different brood cells (queen, worker and honey pots) observed in the natural nest are presented in Table 1.

Similar observations were recorded by Thakur (2002) who reported bumble bee *B. haemorrhoidalis* nests underground. Taylor and Cameroon (2003) also studied the nest construction and architecture of *B. transversalis*. They found that nests were constructed from leaf pieces and grass which kept the nest dry during high humidity. In similar studies, Katayama *et al.* (1995) observed the nests of Japanese bumble bee (*B. deuteronymous maruhanobachi)* and found that the honey pots were framed on the periphery and worker cells on the inner side of the nest.

At higher altitude (2300m), the average length and width of queen cells, honey pots and worker was 16.56±2.1 and 12.55±0.27; 15.31±0.25 and 12.91±0.23; and 13.16±0.79 and 10.15±1.07 mm, while at lower altitude (1250m), the above measurements were 20.57±0.75 and15.20±0.97; 20.35±0.68 and 16.32±0.83; and 14.24±0.86 and 10.01±1.03mm, respectively (Table 2). Honey pots were located at the periphery of both the nests. Gonzalez *et al.* (2004) also found the similar observations in the nest architecture of bumble bees. Hoffmann *et al.*, (2004) also recorded similar dimensions of worker cells, queen cells and honeypots of *B. melaleucus* to the size of 16.0±3.39; 23.9±0.33 and 20.6±4.24mm, respectively.

Refinement of bumble bee rearing technique: The rearing of bumble bees under laboratory conditions started with the capturing of fecundated bumble bee queens, which came out of hibernation and searched for new habitat or during collection of pollen and nectar at the onset of spring. During February–March, the major flora sustaining bumble bee queen population was found to be *Caryopteris bicolor*, *Scutellaria linearis*, *Salvia moorcroftiana*, *Lavendula* sp., *Lupinus mutabilis*, *Delphinium* sp. and *Jasminum humile* (Table 2). During April-May, the queens were found to collect pollen from *Salvia moorcroftiana*, *Nicotiana tobaccum*, *Punica granatum* and *Jakaranda mimmosaefolia* and the queens were trapped while foraging on these plants. Some queens were also collected when they were searching for

Table 1. Observations on different features and dimensions of the nests at different altitudes

Features	Nest 1 (2300m) Jubbal	Nest 2 (1250m) Nauni		
Dimension of nest (cm)	12.x 6.8cm	17.25cm (diameter) and 7cm (height.)		
Shape	Circular	Oval		
Nesting material	Pine leaves and small twigs	Grass, leaves, small wooden pieces and some plastic material		
Water Saturation	Wet at bottom (saturated)	Dry at bottom		
Compactness	Scattered	Compact		
Nest depth	62cm	90cm		
Tunnel length	139.4cm	150cm		
Queen cell length	16.56±2.1	12.55±0.27	20.57±0.75	15.20±0.97
Worker cells	13.16±0.79	10.15±1.07	14.24±0.86	10.01±1.03
Honey pots	15.31±0.25	12.91±0.23	20.35±0.68	16.32±0.83

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Table 2. Important flora harbouring bumble bee queens during different months

Month	Botanical Name	Common name	Trapping Time	No. of queens collected
February	*Caryopteris bicolor*	Caryopteris	Evening	2
	Rosmarinus officinalis, Lupinus mutabilis	Rosemary, Lupin	Morning, Evening	2, 4
March	*Caryopteris bicolor, Lavendula* sp.	Lavendula	Evening, Morning	5,1
	Delphinium sp.	Larkspur	Morning	4
	Scutellaria linearis	Scutellaria	Evening, Morning	2
	Jasminum humile	Chameli	Evening	1
April	*Salvia moorcroftiana*	Salvia	Evening	3
	Salvia moorcroftiana Nicotiana tobaccum	Wild tobacco	Morning, Evening	2, 2
	Punica granatum	Wild pomegranate	Evening	3
May	*Jakranda mimmosaefolia*	Gulmohar	Morning	5

the new home sites by chasing them. The flora enlisted above was found to play an important role in sustenance of bumble bee population in nature (Table 2). Similar results were observed by Kashyap (2008) who also observed bumble bee queens on these flora during the months of February, March and April, respectively. Refined domiciles for initiation of bumble bee colonies revealed (Table 3) that two-chambered boxes with sliding base and top D1 and D2 were preferred as all the spring collected queens initiated their colonies. The acceptance (100 per cent) was significantly higher as compared to D3 and D4 with partial acceptance. Colony rearing, wooden two-chambered box with perforated base (25 ×20×15cm) have no acceptance during February while during March, April and May, it was found to be 66.66, 33.33 and 66.66 per cent, respectively. Similarly, hoarding cages with sliding perforated base having feeding provisions (33x20x10cm) had zero per cent acceptance in February, 33.33 per cent in March, 66.66 per cent in April and no acceptance during May. The wax secretion was earlier in queens captured during April and May (5.91 and 4.25 days, respectively) than February and March (6.58 days), while the queens captured during early spring (February-March) had more acceptability for artificial domiciles (Table 4), which is in conformity with the observations of Kashyap (2008). Domiciles with dimensions 15×12×8cm (D1) and 16×12×10cm (D2) were found to be most acceptable by the queens captured during early spring and the acceptances for these domiciles were found to be 100 per cent but the mean difference was found non-significant (Table 4). Horber (1961) observed that small boxes of size 7.5x7.5x5cm can be successfully utilized for the domestication of bumble bees with 60-100 per cent acceptability.

Queens collected during February-March took more time for wax secretion and have cent percent acceptance for the domiciles D1 and D2. However, during April-May, partial acceptance of domiciles D1 and D2 was observed and queens took less time for acceptance of domiciles at this time (Table 4). Similarly, domiciles D3 and D4 did not showed any acceptance during February, whereas showed partial acceptance during March, April and May. Acceptance was found to be early in the domiciles D3 and D4 during April-May than in February-March collected queens. During May, the workers emergence took place earlier (24.44 days) while in April, March and February the time for emergence after wax secretion was observed to be 26.77, 27.22 and 26.44 days, respectively. Similar results were observed by Kashyap (2008). During the rearing experiment, the queens

Table 3. Acceptance of artificial bumble bee rearing boxes during different months

Months	Acceptance (%) of bumble bees for different refined domiciles*				
	D1	D2	D3	D4	Mean
February	100	100	0	0	50
March	100	100	66.66	33.33	75
April	33.33	33.33	33.33	66.66	41.66
May	33.33	66.66	66.66	0	41.66
Mean	66.66	75	41.66	25	
CD(P=0.05) Domiciles	=	35.11			
Month	=	37.15			

* D1 = Damicile 1 (15x12x8cm); D2 = Damicile 2 (16x12x10cm); D3 = Damicile 3 (25x20x15cm); D4 = Damicile (33x20x10cm)

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Table 4. Time required (days) for initiation and emergence of bumble bee after captivating queens during different months

Months	Initiation					Emergence				
	D1	D2	D3	D4	Mean	D1	D2	D3	D4	Mean*
February	9.33	9.00	9.66	8.67	9.16	25.67	25.67	28.00	Nil	26.44
March	5.66	7.00	7.00	6.66	6.58	27.67	26.67	27.33	Nil	27.22
April	6.00	5.33	7.00	5.33	5.91	27.33	27.33	25.67	Nil	26.77
May	3.66	5.00	4.00	4.33	4.25	24.67	24.67	24.00	Nil	24.44
Mean	6.16	6.58	6.91	6.25		26.33	26.25	26.25	Nil	
CD(P=0.05)										
Domiciles					1.34					2.91
Month					2.04					2.76

*Mean of D_1, D_2 and D_3

captured fed with pollen pellets/ powder and sucrose/ sugar solution. During February-March required more amount of pollen (10g), whereas the queens captured during April-May required 5g pollen. With an increase in activity of queen and the emergence of workers, the quantity of pollen and sucrose fed to the queen was increased (5-12g pollen and 2-10ml sucrose solution) under laboratory conditions (Table 5). Similarly under room temperature, the average quantity of sugar solution and pollen fed 5-15g and 2-10ml per three days, respectively. These results were found to be in conformity with the results of Thakur *et al.* (2005) and Pridal and Hofbaeur (1998).

Utilization of bumble bee under protected conditions for the pollination of cucumber: The fruit length was significantly longer (20.75cm) from vines pollinated by bumble bees being on a par with the open pollinated ones (20.00cm), followed by 16.44cm length in control block.

Bumble bee pollination resulted in significant increase in fruit weight (413.62g) and diameter (11.01cm) being on a par with the fruit weight (548.88g) and diameter (11.89cm) of fruits obtained in open pollination conditions. In control pollination, the fruit weight (262.75g) and diameter (8.39cm) were significantly lower as compared to open and bumble bee pollination (Table 8). Similar results were observed by Stanghellini *et al.* (2000) who noticed an increase in the weight and diameter of cucumber when bumble bees were utilized for the pollination. Bumble bees and open pollinated flowers yielded fruits having significantly more seeds The number of seeds per fruit were 331.20 from control plots, which were significantly less as compared to other treatments. Similarly, the weight of 1000 seeds was significantly higher (31.50g) in fruits of bumble bee pollinated plots, followed by 29.20g and 27.55g extracted from open pollinated and control plots, respectively (Table 6).

The fruit yield (76.97%) in bumble bee-pollinated and open pollinated crop (66.16%) was significantly higher than in the plants excluded from pollinators (control).

Bumble bee pollinated plants had significantly lowest crooked fruits (16.18%), followed by 25.20 per cent in open pollinated plants, whereas, significantly highest number of crooked fruits (36.45%) were observed in plots devoid of

Table 5. Feeding of bumble bees under artificial conditions

	Feeding material	Quantity
Laboratory conditions	Sucrose (50%)	2-10ml sucrose (50%)
(26.9°C; 65%RH)	Pollen pellets	5-12g pollen pellets
Room Temperature conditions	Sugar (50%)	2-10ml sugar (50%)
(32-36°C and 50-60%RH)	pollen pellets	5-15g pollen pellets or pollen powder

Table 6. Effect of different modes of pollination on cucumber grown under protected conditions

Pollination Type	Length (cm)	Diameter (cm)	Weight (g)	Seeds/fruit (No.)	Weight (1000 seed g)	Fruit yield (%)	Crooked fruits (%)	Healthy fruits (%)
Bumble bee	20.75	11.01	413.62	422	31.50	76.97	16.18	83.62
Open	20.00	11.89	548.88	434	29.20	55.10	36.45	64.55
Control	16.44	8.39	262.75	331.20	27.55	68.16	25.20	74.80
CD(P=0.05)	2.39	0.88	165.387	45.44	0.54	9.97	5.78	5.14

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pollinators. The results are in conformity with the results of Stanghellini *et al.* (1997) who reported less abortion of cucumber fruits in bumble bee pollination. Similarly, Hodges and Baxendale (1991) reported less crooked fruits in bee-pollinated plants because of proper pollination of flowering crop plants and observed more number of crooked fruits in control and open conditions due to inappropriate pollination.

In bumble bee pollinated plants, the per cent increase in the fruit set and healthy fruits were 27.64 and 22.81 over the control (Table 7). However, percentage of crooked fruits was reduced to 65.62 per cent in bumble bee-pollinated plants than the plants which were excluded of pollination.

Similarly, an increase in the percentage of fruit length, diameter and weight of cucumber fruits was recorded in the cucumber vines pollinated by bumble bees was 20.78, 23.80 and 36.48 per cent, respectively as compared to the plants with no pollination (control). Simultaneously, per cent increase in the seed number and weight (1000 seeds) was 21.52 and 12.54 per cent, respectively in bumble bee pollinated plants. Similar results were observed by Stanghellini *et al.* (2000) who noticed an increase in the weight and diameter of cucumber when bumble bees were utilized for the pollination resulting in increased fruit set and yield.

Table 7. Effect of bumble bee pollination on fruit and seed parameters of cucumber grown under polyhouse conditions

Parameters	Per cent increase (%)
Fruit set	27.64
Healthy fruits	22.81
Crooked fruits*	65.62
Fruit length	20.78
Fruit diameter	23.80
Fruit weight	36.48
Seed number	21.52
Weight (1000 seeds)	12.54

*Reduction in per cent of crooked fruits

There is an increase in the cost benefit ratio in poly house and was found to be 1: 2.02 with 22% increase in the total returns in bumble bee pollination cucumbers than

Table 8. Cost-benefit ratio of cucumber grown under protected conditions

Parameter	Cost/100sq m	Fixed Costs (Rs.) per polyhouse (100m²)	
Human labour	2400	Rental value of polyhouse @Rs. 800/month	4000
Land preparation	150	Management cost	1000
Nursery Raising	40	Risk margin	500
Transplanting	40	Total fixed cost	5500
Weeding	600		
Irrigation	400		
Inter-culture operations	300		
Harvesting	240		
Seed	50		
Fertilizer	1000		
Crop protection	400		
Miscellaneous	1000		
Total variable cost	6620		
Total	12,120		
Total Output	1228.8 kg		
Total returns @ Rs. 20/kg	24,576		
Net profit	12,456		
Crop benefit ratio	1:2.02		

Bumble bee pollination

Total yield from bumble bee pollinated plots = 1175.04 kg
Total returns @ 20Rs/kg = 23,500

Control

Total yield from control plots = 302.7 kg
Total returns@ 20Rs/kg = 6054

Hypothetically, if number of control (no pollination) plots taken equal to bumble bee pollinated plots (24) then,

Total yield = 921.6 Kg (total plants yield)
Total returns@20Rs/kg = 18,432 Rs

Difference between Bumble bee pollinated and control returns = 5068 Rs (23,500-18,432=5068 which is 22 per cent more than returns from control blocks).

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control (Table 8).

The present study on bumble bee nest architecture revealed the complex composition of nests which can be utilized in creating more efficient rearing domiciles with complete acceptability. Refined domiciles provide a better opportunity for the researchers to carry their bumble bee rearing experiments smoothly without making unwanted disturbances to the developing colonies leading to healthy bumble bee colonies for the pollination of crops. Bumble bee pollination was found to be better than other modes of pollination in cucumber under protected conditions yielding good and high quality fruits as compared to the one grown in open and control conditions. Cost- benefit ratio determining the benefit to the farmers was found to be double as compared to open conditions. This study highlight the immense importance and role played by bumble bees in the pollination of crops and opens new vision and opportunities for the farmers to utilize them for crop pollination which would ultimately benefit them in increasing their economy.

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Effect of Growth Hormones on Rooting of Branch Cuttings in Dek (*Melia azedarach* Linn.)

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Melia azedarach Linn., dek is a moderate-sized deciduous tree with a short trunk and spreading crown of deep green feathery foliage, reaching a height of 9-18m and a girth of 1-1.2m with a straight cylindrical bole upto about 2.5m long. It is doubtfully indigenous to north-west India along the sub-Himalayan tract, but now is naturalized throughout the tropics where it is planted in the arid, semi-arid and also in the semi-moist areas. It is also found in Iran, Pakistan, Burma, Malaysia, Philippines, the Hawaiian Islands, Cuba and China. In India, it occurs in eastern alluvial secondary evergreen forests (2B/2S2) and southern dry mixed deciduous forests (5A/C3) as reported by Champion and Seth (1968). As evidenced by its wide distribution, it is capable of withstanding wide climatic variations.

In Punjab, dek is considered as an important agroforestry tree because of its adaptability to varied climatic and soil conditions. *Melia azedarach* based agroforestry systems has great acceptability among farmers of the state for its diversified uses, relatively fast growth, compatibility with agricultural crops and economic returns, which are comparable with other promising agroforestry tree species. This tree has a great potential in diversification of dominated poplar and eucalypt based agroforestry systems in Punjab in the years to come. However, the availability of quality planting stock of the species is a big question and the material developed through seed has enough variability due to its cross-pollinated behavior therefore, necessitated its vegetative propagation. Vegetative propagation technology helps in producing true to type plants for better quality and higher yield. The potential to bulk up high genetic gains within short period at an early age, favours the operational use of vegetative propagation (Libby, 1974). Vegetative propagation can be done either by macro-propagation (cuttings, layering, grafting, etc.) or by micro-propagation (through tissue culture). Tissue culture is more expensive, technical and laborious method of reproduction than macro-propagation. Vegetative propagation through stem cuttings has been commercially exploited in poplar, willow, mulberg and many other fast growing hard wood species but in *Melia azedarach*, cuttings do not root easily. Species is also rated in a 'difficult to root' category (Rawat *et al.*, 1994).

The rooting of cuttings is a complex process; growth hormones, season of planting the vegetative propagules, position of excision of stem cuttings, micro-environment, etc. play a crucial role in successful rooting of any tree species. The efforts for development of suitable methodologies for vegetative propagation especially, which are hard to root for rapid and mass production of clonal material are at its beginning. In *Melia azedarach*, very few studies have been carried out in comparison to neem (another important member of Meliaceae family) and other species like poplars and eucalypts across the globe. With the consideration of many limitations in macro-propagation of dek, the present study was attempted to know the response of different concentrations of growth hormones for rooting of branch cuttings for mass propagation.

The present study was carried out at the experimental area of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana during spring (February) and rainy seasons (August) to know the suitable season and root initiating hormones. The climate of the area is sub-tropical to tropical. The temperature is maximum during summer months i.e., May and June and means monthly day temperature is 39.1°C. On the other hand, it is lowest during winter months i.e. December and January (means daily temperature is 6°C). Average annual rainfall of area is 704 mm of which 75-80 per cent is received during the rainy season i.e. July to August.

During each season, current year's growth was used to make cuttings. The branches were collected in the morning at about 0900 hours. These were kept in a bucket containing water. The cuttings of uniform length (20-22 cm) and diameter (1.5-2.0 cm) with alteast 3-4 buds on each cutting were prepared with the help of secateur. The cuttings were immediately kept in water before giving treatments. The branch cuttings used for vegetative propagation were treated with six concentrations of auxins i.e., 500 ppm IAA, 1000 ppm IAA, 2000 ppm IAA, 500 ppm IBA, 1000 ppm IBA and

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2000 ppm IBA for 15 seconds and one control (untreated cuttings) during both the seasons under two environments i.e., open nursery and mist chamber.

The experiments were laid out in a Split Plot Design with three replications. Observations were recorded on sprouting initiation, total time taken for complete sprouting, sprouting percentage, callusing percentage, decaying percentage, rooting percentage, number of roots per cutting, length of longest root, shoot length, shoot diameter, fresh and dry weight of root and shoot, total plant dry biomass and root : shoot ratio. Pooled data of both the environments are discussed here.

As evidenced from the data presented in Table 1, there were significant variations among treated and untreated branch cuttings for sprouting initiation. Among treated cuttings, maximum 11.54 days were taken for sprouting at 1000 ppm IBA concentration followed by statistically at par values of 11.25 days 2000 ppm IBA and minimum (9.87 days) 500 ppm IAA. The untreated cuttings took same minimum number of days (9.87) for sprouting initiation. The total time taken by stem cuttings for complete sprouting varied from 15.62 to 18.87 days. The untreated cuttings took minimum number of days (15.62 days) to complete sprouting, whereas, maximum days i.e. 18.87 were taken by 2000 ppm IBA treated cuttings. The total time for completion of sprouting was significantly less in IAA treated cuttings as compared to IBA treated cuttings. The sprouting percentage of the cuttings varied between 50.20 (untreated) to 64.99 per cent (1000ppm IBA). Overall, the sprouting percentage in IAA treated cuttings was better than IBA treated cuttings with the exception in 1000 ppm of IBA.

Rooting percentage did not vary significantly in the cuttings treated with different concentrations of IAA and recorded lower values for rooting in comparison to IBA except IBA 2000 ppm, where the rooting percentage was minimum among all the hormonal treatments (13.33%). Highest rooting (23.33%) was noticed in the 1000 ppm IBA treated cuttings followed by the significantly lower value (19.16 %) with IBA 500 ppm. The root numbers per cutting was highest in 1000 ppm IBA (8.81) followed by significantly lower value of 8.05 in 500 ppm IBA. Comparatively, the root numbers per cutting were more in IBA treated cuttings than that of IAA treated cuttings. The maximum length of longest root (15.65 cm) was recorded in 1000 ppm IBA treated cuttings followed by significantly lower value (12.39 cm) in 500 ppm IBA, whereas, other values within and between different concentrations of IAA and IBA for length of longest root did not show significant variations. Untreated cuttings did not produce any root. Similar differential behaviors for rooting response in the branch cuttings of *Melia azedarach* have been reported by Gupta *et al.* (1989); in *Melia composita* by Luna and Kumar (2006a,b); Luna *et al.* (2007) and in *Azadirachta indica* by Palanisamy *et al.* (1998); Singh and Chander (2001); Gill *et al.* (2006). Haissig (1986) has explained that division of first root initial cells depends upon either exogenous or endogenous auxins. As early as root initial cell start showing response in stem cuttings, it results in increase in number of root in cuttings. It indicates that the application of IBA may have mobilized total soluble sugars and phenols to the rooting zone more efficiently and utilized them for differentiation. It has been reported in several other species also that auxins generally promote rooting at particular concentration, which varied with plant species and nature of auxins (Hartmann and Kester, 1983). The reduction in rooting at higher auxin concentration was attributed to super optimal level by Bhardwaj (2000), which might also be true in the present study.

The maximum shoot length (16.98 cm) and diameter (0.76mm) was recorded in 1000 ppm IAA treated cuttings followed by at par value of 16.84 cm in 1000 ppm IBA. There were no significant variations in shoot length at 500 ppm and 2000 ppm concentration of IBA. Minimum shoot diameter of 0.55 mm was noticed at 2000 ppm IAA. Shoot diameter of sprouts decreased significantly with increase in concentration of auxins beyond 1000 ppm in IAA and IBA. These findings confirm the earlier reports of Verma *et al.* (1996) and Gill *et al.* (2006) in *Azadirachta indica.*

The highest fresh shoot weight per cutting (12.50 gm) was recorded in 1000 ppm IBA treated cuttings followed by non-significant values of 12.02, 10.52, 9.75 and 9.41 gm in 500 ppm IAA, 500 ppm IBA, 1000 ppm IAA and 2000 ppm IBA, respectively. Whereas, minimum fresh weight of shoot (8.40 gm) was recorded in the cuttings treated with IAA 2000 ppm. The fresh and dry root weight followed the same trend and recorded higher values at IBA 1000 ppm followed by 500 ppm IBA, 1000 ppm IAA and 500 ppm IAA. Palanisamy *et al.* (1998) also observed similar results with IBA and IAA treatments in *Azadirachta indica*. The differences in shoot and root dry weight were reflected in total dry weight. The untreated cuttings initially sprouted but then dried up probably because of breakdown of reserve food material.

The values of root:shoot ratio on dry weight basis presented in Table 1 ranged from 0.015 (500 ppm IAA) to 0.036 (2000 ppm IBA). The overall root : shoot ratio was significantly better in IBA concentrations, which indicated that rooting was more in IBA treated cuttings than IAA treated cuttings. Auxins are involved in plant root formation, lateral bud inhibition and activation of cambial cells. It has been well accepted and confirmed many times that auxins naturally or artificially applied are required for initiation of adventitious

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Table 1. Effect of growth hormones on rooting of branch cuttings and other related parameters

Growth hormones/ Parameters	IAA			IBA			Control	CD (0.05)
	500 ppm	1000 ppm	2000 ppm	500 ppm	1000 ppm	2000 ppm		
Days of sprouting initiation	9.87	10.08	10.20	10.58	11.54	11.25	9.87	0.38
Days taken for completion of sprouting	16.20	16.79	17.04	17.58	18.25	18.87	15.62	0.52
Sprouting percentage*	64.16 (56.35)	63.74 (56.49)	62.49 (55.24)	62.49 (55.83)	64.99 (57.48)	59.99 (53.41)	50.20	2.45
Rooting percentage*	15.55 (18.96)	16.24 (20.10)	15.06 (18.26)	19.16 (22.17)	23.33 (25.10)	13.33 (18.41)	00.0	1.82
Number of roots per cutting	7.05	7.95	7.27	8.05	8.81	7.99	0.00	0.17
Length of longest root (cm)	11.68	12.23	11.21	12.39	15.65	11.12	0.00	2.75
Shoot length (cm)	15.97	16.98	15.35	14.71	16.84	14.57	0.00	0.55
Shoot diameter (mm)	0.65	0.69	0.55	0.74	0.76	0.67	0.00	0.04
Shoot fresh weight (gm)	12.02	9.75	8.40	10.52	12.50	9.41	0.00	3.62
Shoot dry weight (gm)	1.91	1.49	1.29	1.81	1.96	1.46	0.00	0.53
Root fresh weight (gm)	0.11	0.11	0.10	0.13	0.14	0.10	0.00	NS
Root dry weight (gm)	0.03	0.04	0.03	0.06	0.07	0.05	0.00	NS
Total fresh biomass (gm)	12.14	9.87	8.50	10.65	12.64	9.46	0.00	3.62
Total dry biomass (gm)	1.94	1.54	1.33	1.87	2.04	1.51	0.00	0.53
Root : shoot ratio	0.015	0.026	0.023	0.033	0.036	0.034	0.00	0.015

*Arc sine transformed values in parentheses

roots on stem cuttings (Nanda, 1970). Division of first root initiation cell are dependent upon either applied or endogenous auxins. However, formation of root initials in stem depends upon the nature, auxins in plant plus synthetic auxin applied in solution or powder formulation, together lead to synthesis of ribonucleic acid, which are involved in initiation of root primordia (Hartmann and Kester, 1983).

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Genetic Variability for Physico-chemical Characterization in Jackfruit Collection of Karnataka

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Jackfruit (*Artocarpus heterophyllus* Lam.) native to Western Ghats of India, is found up to 1500 m and has tremendous diversity. The popularity of jackfruit as a commercial crop is very meager due to wide variation in fruit quality (Medagoda, 2007). In order to assess the diversity in this crop, there is a need to study the variability of jackfruit. In the present investigation, our goal was to study the variability existing in physico-chemical qualities jackfruit selection in different parts of Karnataka.

In the present study, 13 jackfruit types selected from different places of Karnataka (Table1). The fruits were harvested at mature ripe stage and then transported to the laboratory to study the physico- chemical characters of bulbs at edible ripe stage.

Highest total number of fruits per tree (125), fruit weight (15.03 kg), fruit length (48cm), fruit breadth (29.0cm) number of bulbs per fruit (404), pulp weight (6.36 kg) and pulp percentage (48.20%) was recorded in SKP-1 genotype. Bulb weight (45.67 g) was highest in SNG-1 followed by AVT-3 the lowest bulb weight was in SMG-1 (14.67 g). Bulb length (6.85 cm) was highest in SNG-1 followed by SKP-1. The lowest bulb length was in RMD-5 (4.57 cm). Bulb width was found highest in SNG-1 followed by AVT-1 and was lowest in RMD-4. Seed weight was highest in SNG-1 and lowest in SMG-1(3.60 g). Similar seed length (4.05 cm) was in SNG-1 and followed by KLD-1. Seed width (2.03 cm) was highest in SNG-1, whereas lowest in SMG-1(1.52 cm). The chemical characters showed huge variation among 13 collections (Table 2). TSS was maximum in RMD-2 (32.48ºB) followed by KLD-1 (32ºB). It was significantly less in SKP-2 (13.5ºB) which is not a desirable character for desert purpose (Gangamma, 2005; Jagadeesh *et al.*, 2010). Significantly maximum total sugar and reducing sugar content was recorded in the genotype RMD-2 (25.10 % and 11.43% respectively). The minimum total sugar and reducing sugar content was recorded in the genotype AVT-1 (15.42% and 6.21% respectively). Conclusively above results many desirable characters were found in SKR-1 for desert purpose and such genotypes need to be conserved and multiplied for dissemination for plantation to enhance fruit productivity.

Table 1. Physical characters of desert type jackfruit selections

Genotypes	No of fruits tree^{-1}	Fruit weight (kg)	Fruit length (cm)	Fruit breadth (cm)	No. of bulbs fruit^{-1}	Pulp weight (kg)	Pulp percentage
AVT-1	100	8.58	38.2	20.50	92.00	4.10	47.17
KLD – 1	90	11.28	39.00	24.50	209.00	3.53	41.40
KLD – 2	95	4.00	24.80	18.00	34.00	0.83	20.80
RMD – 1	100	6.16	30.00	25.50	288.00	2.83	46.03
RMD – 2	80	5.35	35.00	16.00	153.00	1.92	36.00
RMD – 3	75	13.50	47.00	27.00	159.00	5.80	38.61
RMD – 4	50	9.96	38.00	20.00	212.00	1.82	18.27
RMD – 5	25	6.78	30.00	19.00	160.00	2.85	42.03
SKP – 1	125	15.03	48.00	29.00	404.00	6.36	48.20
SKP– 2	75	12.03	38.00	24.50	288.00	6.44	34.90
SMG – 1	100	7.24	37.20	21.50	247.00	1.35	18.64
SNG-1	70	13.34	44.00	24.50	156.00	5.56	41.60
SRS-1	120	8.70	42.00	20.00	227.00	3.60	41.30
Variance	1017.3	11.96	45.44	14.60	8904.02	3.01	112.52
Mean	81.15	9.56	38.33	21.75	823.70	3.39	41.96
S.D.	31.89	3.45	6.74	3.87	94.36	1.73	10.60

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Table 2. Bulb, seed and chemical characters of jackfruit genotypes

Genotypes	Bulb weight (g)	Bulb length (cm)	Bulb width (cm)	Seed weight (g)	Seed length (cm)	Seed width (cm)	TSS (°B)	Total sugars (%)	Reducing sugars (%)
AVT-1	39.00	6.48	3.76	5.00	2.85	2.01	17.00	15.42	6.21
KLD – 1	25.33	6.17	3.19	7.33	3.67	1.76	32.00	21.24	8.73
KLD – 2	35.67	5.61	3.85	7.33	3.20	2.02	25.80	20.78	8.62
RMD – 1	25.00	4.66	2.81	4.33	2.92	1.61	30.30	24.72	10.92
RMD – 2	18.33	4.68	2.97	5.00	2.91	2.02	32.48	25.10	11.43
RMD – 3	37.33	6.40	3.40	6.33	3.01	1.93	31.00	22.36	10.42
RMD – 4	20.00	5.50	2.39	4.67	2.88	1.95	28.99	24.53	9.46
RMD – 5	24.00	4.57	2.60	4.00	2.92	1.52	20.00	21.66	8.11
SKP – 1	25.00	6.70	2.96	3.67	2.84	1.74	21.10	23.11	10.48
SKP– 2	16.33	6.36	2.67	6.67	4.05	1.87	13.50	19.49	7.13
SMG – 1	14.67	4.58	2.64	3.60	2.95	1.60	17.80	18.43	7.10
SNG-1	45.67	6.85	3.99	7.50	3.91	2.03	25.50	21.62	8.17
SRS-1	19.00	5.42	2.88	5.33	3.10	1.90	22.00	21.43	8.26
CD (0.05)	3.11	0.76	0.40	1.14	0.30	0.23	0.97	0.26	0.13

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Effect of Container Types and Potting Media on the Growth of *Melia composita* Willd. Seedlings

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Melia composita Willd., a fast growing deciduous tree commonly reported from the tropical moist deciduous forests of the Sikkim Himalayas, North Bengal and upper Assam, the Khasi hills, and the Western Ghats, at altitudes of 1,500-1,800 meters (Brandis, 1906; Parthiban *et al.*, 2009) belongs to family Meliaceae. The tree is a good source of useful timber. Its wood can also be used as packaging cases, cigar boxes, ceiling planks, building and construction materials, agricultural implements, pencils, matchboxes/ splints, musical instruments, tea boxes and ply board. It is also a good fuel wood with calorific value of 5.043-5,176 calories. It seeds every year and can be propagated either by direct sowing or by planting out nursery seedlings. The tree is capable of withstanding wide range of climatic conditions. Since, tree grows rapidly, therefore can be used for onfarm plantation. It is used on boundary and for shade purpose as well. It is being cultivated in the arid and semi-arid as well as semi- moist areas of the country. Due to its fast growth and multiple uses, it is emerging as a favourite tree for agroforestry plantations not in northwestern states but extending in all four directions of the country.

Increasing interest of farmers in *Melia* will certainly create a demand for quality seedlings in the coming years. The success of any plantation program largely depends on the production of quality seedlings, which in turn depends upon the quality of seeds, the growing medium and even on the containers in which seeds are sown. Thus, the present study was conducted at the Experimental Farm of the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu at Chatha to find the best container types and potting media for the growth of *M. composita* seedlings. The nursery site is located in sub-tropical zone, characterized by cool winters and hot summers. The average annual precipitation is 1000 mm, most of which is received in during July-September months in the form of rains. Maximum temperature rises up to 45°C and minimum temperature falls upto 2°C. Three different potting mixtures were prepared by using Soil, Sand, Farm Yard Manure (FYM) and Vermicompost (VC). The various potting mixture and their proportionate ingredients used are presented in table 1. The aeration porosity, water holding porosity and total porosity of the growing media was determined for containers as described by Gessert (1976) and Whitcomb (1988).

Two different root trainers with a volume of 300 cc and 250 cc (C1 and C2, respectively) and polythene bags of two different sizes of 28 x 23 cm and 24 x 16 cm (C3 and C4, respectively) were used. The experiment was laid in CRD factorial (Completely Randomized Design), having two factors i.e., container type and growing media at four and three levels, respectively, replicated thrice. There were thirty six plants and observations were recorded on nine randomly selected plants per treatment per replication. The entire data generated from the present investigations were analyzed statistically.

The findings of the present investigation revealed that irrespective of potting media, seedlings raised in bigger sized polybags and root trainers performed best. The *M. composita* seedlings grown in polybags of size 28 x 23 cm registered maximum biomass among all the treatments. The use of

Table 1. Details of potting mixture, ingredients and their proportions, nutrient status and aeration, water holding and total porosity of different growing medium

Medium	Ingredients	Proportion	pH	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Aeration porosity (%)	Water holding porosity (%)	Total porosity (%)
M1	Soil	1	7.90	208.12	15.20	158.00	7.6	48.0	41.6
M2	Soil + Sand + FYM	2:1:1	7.35	278.63	15.90	165.55	8.1	58.3	50.2
M3	Soil + Sand + VC	2:1:1	7.48	290.45	16.10	172.50	7.8	49.5	41.7

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Table 2. Effect of container types and potting media on the growth of *M. composita* seedlings

Treatmentscombinations	Height (cm)	Collar diameter (mm)	Shoot dry weight (g)	Root dry weight (g)	Total seedling dry weight (g)	Root : shoot ratio
C_1 (Root trainer size 300 cc) M_1 (Soil)	16.55	1.67	0.22	0.12	0.35	0.58
C_1 (Root trainer size 300 cc) M_2 (Soil+ Sand+ FYM)	17.98	2.22	0.51	0.18	0.69	0.37
C_1 (Root trainer size 300 cc) M_3 (Soil+ Sand + VC)	15.88	2.05	0.31	0.25	0.56	0.93
C_2 (Root trainer size 250 cc) M_1 (Soil)	13.11	1.33	0.20	0.02	0.22	0.15
C_2 (Root trainer size 250 cc) M_2 (Soil+ Sand + FYM)	15.00	1.55	0.35	0.03	0.39	0.10
C_2 (Root trainer size 250 cc) M_3 (Soil+ Sand + VC)	12.33	1.58	0.30	0.04	0.34	0.13
C_3 (Polybag 28 cm x 23 cm) M_1 (Soil)	27.22	2.63	0.60	0.09	0.70	0.13
C_3 (Polybag 28 cm x 23 cm) M_2 (Soil+ Sand+ FYM)	31.00	3.26	1.05	0.10	1.15	0.10
C_3 (Polybag 28 cm x 23 cm) M_3 (Soil+ Sand +VC)	28.00	2.71	0.19	0.13	0.32	0.72
C_4 (Polybag 24 cm x 16 cm) M_1 (Soil)	15.11	1.98	0.04	0.05	0.10	0.68
C_4 (Polybag 24 cm x 16 cm) M_2 (Soil+ sand+ FYM)	18.00	2.03	0.09	0.06	0.15	0.62
C_4 (Polybag 24 cm x 16 cm) M_3 (Soil+ sand +VC)	17.55	2.18	0.11	0.06	0.17	0.48
CD (0.05)	NS	NS	0.10	0.33	0.10	0.22

FYM and Vermicompost in the potting mixtures greatly benefited the growth and quality of the plants as compared to the potting mixture containing only soil. Comparatively higher values were recorded for plant height, collar diameter, shoot dry weight, total seedling dry weight and root:shoot ratio in large polythene bag of size 28 x 23 cm and in bigger root trainers of size 300 cc as compared to their smaller sized counter parts though the differences were non-significant for height and diameter. Similar results have been reported by Ferdousee *et al.* (2011). Container depth and water retention are strongly related and can affect the water-holding capacity of the potting mixture. The taller the pot, the higher the column of medium, usually resulting in proportionally more medium in the pot that is well drained compared to short or squat pots. This could also probably be attributed to higher water and nutrient availability in containers with higher volumes. Similar results have also been reported by Hopkins and White (1984) and Milks *et al.* (1989) while studying the growth of plants in containers.

Further, comparatively better results were observed in media containing Soil+Sand+FYM in 2:1:1 ratio. This may be possibly due to the fact that this media had higher air porosity, water holding porosity and total porosity than other treatments (Table 1). Bragg and Chambers (1988) have reported that aeration porosity is considered to be the most important physical property of any growing mixture. Therefore, in the present study, the medium containing Soil +Sand+FYM (2:1:1) was found to be more suitable because of the better physical properties and enhanced nutrient level.

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Indian Journal of Ecology

Growth Behavior of Poplar and Fruit Crops in Silvi-Horticulture System under Arid-Irrigated Conditions of Punjab

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In the present scenario of increasing population and shrinking land resources, the integrated production systems have emerged as a key factor for sustainable production in India to meet the multiple requirements. In Punjab, due to paddy-wheat rotation, the natural resources has been exhausted to a great extent; underground water level is depleting, the fertility status of soil is reducing and biotic as well as abiotic stress is increasing. Therefore, the emphasis on diversification has focused to bring more area under perennial components i.e., fruit crops and forest trees. Horticulture is one of the best options for the farmers of Punjab owing to its economic profitability, nutritional security, employment generation, etc. However, due to long juvenile phase of fruit trees, the farmers have to grow suitable intercrops for income generation during initial phase. Tree (fruit)–Tree (timber) combination may be the another option for diversification in agriculture. Poplar cultivation may be accentuated due to its ease of propagation and planting, easy establishment, fast growth, straight cylindrical bole, deciduous nature and high returns (Chandra, 2011). Poplar trees are characterized to the addition of organic matter as well as nutrients to soil through litter fall as compared to other tree species. Extensive research work on cultivation of agricultural crops as an intercrops for first 3-4 years in poplar and fruit crops has been done in various parts of India to explore the possibility of income generation. However, the work on cultivation of fruit crop as an intercrop in poplar is limited particularly in arid and semi-arid conditions. Poplar can be grown on a short rotation of 5–7 years and the farmers can make use of inter-space of fruit plants judiciously for economic gains (Chauhan and Mangat, 2006). Multiple cropping has been found economically feasible than traditional rice-wheat rotation and many progressive farmers have adopted such type of cropping system (Chauhan *et al.,* 2007). However, the selection of crops must be based on the principle of minimizing the competitive effect and maximizing the complimentary effect among themselves. Proper care and management are indispensable factors to exploit suitable productivity in the system of intercropping. Therefore, the present investigation has been initiated to study the plant growth behavior of poplar as well as fruit crops when planted in an integrated system under arid-irrigated conditions of Punjab.

The planting of fruit crops viz. peach (*Prunus persica* L. Batsch.) cv. Shan-e-Punjab, guava (*Psidium guajava* L.) cv. Allahabad safeda, plum (*Prunus salicina* L.) cv. Satluj Purple and citrus; Kinnow (*Citrus reticulata* Blanco) was done made in the middle of rows of poplar (*Populus deltoides* Bartr. Ex Marsh.) plants at 6×6 m spacing. The plantation of sole poplar crop and sole fruit crops was also made for comparison to find out best suitable combination. The investigations on plant growth behaviour in terms of scion girth, stock girth, plant spread and canopy volume were carried out. In fruit crops, the scion and stock girth measurements were taken at 6 cm above and below the graft union, respectively. Plant height was measured by measuring pole, while canopy spread was calculated using the formula of Roose *et al.* (1986) after measuring the plant spread in both North-South and East-West. Similarly, in poplar, the total height was measured with measuring pole (in meters) from ground to top and the diameter at base (DAB) and diameter at breast height (DBH i.e., 1.37 m above the ground level) was taken with the help of a digital caliper.

The rootstock and scion girth of peach, plum and guava plants was significantly higher under poplar plantation while, in kinnow, the scion girth was significantly less in comparison to sole crop (Table 1). About 20 per cent increment in stock and scion girth was recorded in peach on inter-cultivation under poplar. Similarly, in plum and guava upto 10 per cent increment in stock and scion girth was recorded. However, significant reduction in scion girth was observed in citrus under poplar plantation, although, the stock girth was not affected significantly. Maximum stock and scion increment was observed in peach under poplar plantation. However, Dhillon *et al.* (2010) reported increment in stock diameter and height of kinnow inter-cultivated with poplar. The height of fruit plants was also effected under poplar plantation; increase in plant height of all fruit plants was recorded under poplar plantation as compared to sole crops. The rate of increment of vertical growth was more in deciduous fruit

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Table 1: Vegetative growth parameters of different fruit crops in Silvi-Horticulture system

Crops	Stock girth (mm)	Scion girth (mm)	Height (m)	Spread (N-S)(m)	Spread (E-W)(m)	Canopy Volume (m^3)
Poplar + Peach	51.67	45.33	1.60	1.31	1.03	1.15
Poplar + Plum	40.33	35.00	1.58	1.07	1.10	0.98
Poplar + Guava	32.00	28.33	1.34	1.02	1.23	0.89
Poplar + Citrus	30.33	23.67	1.29	0.95	1.05	0.67
Sole Peach	38.33	36.33	1.16	1.65	1.46	1.47
Sole Plum	32.30	32.50	1.09	1.59	1.38	1.27
Sole Guava	26.66	25.87	1.11	0.97	1.44	0.85
Sole Citrus	32.00	30.80	1.05	1.10	1.06	0.64
CD (5%)	3.21	2.26	0.08	0.13	0.07	0.12

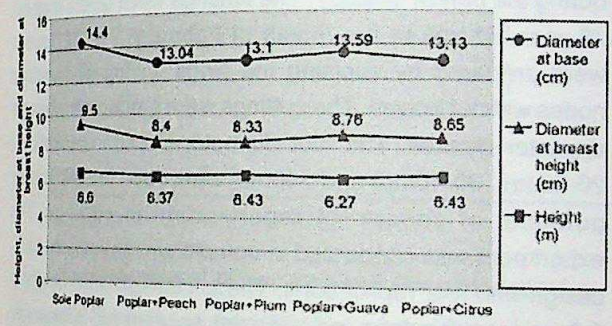

Fig.1. Growth of sole poplar and under Inter-cropping system

crops (peach and plum) than evergreen (citrus and guava) under poplar plantation. The plant spread in north-south direction was significantly reduced in deciduous fruit plants under poplar canopy, but in evergreen fruit plants, the spread was statistically at par in sole crops. Similarly, the plant spread of deciduous fruit plants in east-west direction was also reduced significantly under poplar plantation. The reduction in spread in peach and plum may be due to vertical growth at the expense of horizontal plant spread. The canopy volume of plant was significantly higher in sole deciduous fruit crops but it remains significantly same in case of evergreen fruit crops. Dhillon *et al.* (2010) also reported no effect of poplar canopy on growth of fruit plants except in guava where height and tree spread was significantly higher.

The girth of poplar plants was significantly affected with inter-cultivation of fruit plants. The diameter at base (DAB) of plant was maximum (14.4 cm) in sole poplar crop and minimum (13.04 cm) in peach-poplar combination (Fig.1). Similarly, the diameter at breast height (DBH) was also maximum in sole crop (9.5 cm) as compared to poplar inter-cultivated in all the fruit crops. Trunk girth of poplar in deciduous fruit plants was more affected than evergreen fruit plants. The microclimatic changes due to intercropping are known to affect growth and performance of trees (Tang, 1996). Height of poplar as a sole crop and inter-cultivated with all fruit plants was not affected significantly (Fig.1). However, Dhillon *et al* (2012) reported that growth increment of poplar was significantly higher when planted with fruit plants as compared to sole poplar planting. However, these are initial observations, which may change with time due to perennial nature of both the components.

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Root Rejuvenation in Shoot Cuttings of *Tectona grandis* Under Protected Conditions in New Locality of Western Himalayas

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Tectona grandis Linn. is the most important timber tree species of Indian tropics. Its cultivation has been extended to the sub-tropical parts of Himachal Pradesh and Gangatic plains of northern India. It has some peculiar qualities such as strength, durability and resistance to termites. Propagation by stem cutting is promising techniques of vegetative propagation for establishment of clonal teak plantation on commercial scale. This technique can provide the adequate supply of superior clones in this sub-tropical region and has the potential to provide the clonal material for mass scale propagation for future plantation of the species with assured wood characters.

Quality teak stumps can be produced from seeds, however, the seed yield per tree is low including seed germination, and only few seedlings are produced per 100 seeds. Therefore, propagation through cuttings has been widely used to multiply the elite teak trees obtained from the natural population to exploit the genetic variability. Attempts have been made to understand and improve the adventitious rooting efficiency of cuttings in selected plant species including teak because various intrinsic as well as extrinsic factors are responsible for root formation (Leaky, 1985; Husen and Pal, 2003).

Cutting thickness has significant effect on the rooting per cent of *Populus deltoides* cuttings (Kachlenz, 1958). The branch cuttings of 18-22 mm diameter of *Morus alba* have shown improved survival, rooting and growth performance (Dhiman *et al.*, 1988). Husen and Pal (2001) and Nautiyal *et al.* (1991) found the maximum rooting per cent and shoot growth in *Tectona grandis* with 2000ppm IBA before planting. In general, the rooting behavior of different types of cuttings is affected by nature of species, metabolic behavior response to external stimulus and the reserve food material. Therefore, the present study was conducted to study the effect of cutting diameter and protected environment on the adventitious rooting capacity of shoot cuttings of teak.

The experiment was conducted at Jachh in subtropical region of western Himalayas at an altitude of 667 m above m.s.l., which receives average annual rainfall of 1500 mm. The average temperature under the poly house ranged from 24-41°C and humidity was maintained around 85 ± 2% during the period of study. The cuttings were taken from the 15-year-old tree in the month of February. These cuttings were prepared by excising the twigs having at least two nodes without leaves. The cuttings were graded into different diameter classes. The four diameter classes viz; <20mm, 20-30mm, 30-40mm and >40mm were used to estimate the potential of shoot/root regeneration in cuttings. The experiment was conducted in completely randomized block design with four replications. These cuttings were dipped in 0.3 per cent bavistin (carbandzin) solution for 30 minutes. Thereafter, the cuttings were treated with 2000ppm IBA in talcum powder (Husen and Pal, 2001). So treated cuttings were planted in raised nursery bed in poly-house, prepared by mixing soil, sand and FYM in 1:1:2 ratio, the beds were presoaked with water for 24 hrs. The 50 cuttings in each treatment were planted for study. After 90 days, the cuttings were carefully removed from the rooting medium and observations were recorded on callus formation, sprouting, rooting, number of roots per cutting and the mean length of roots per cutting (cm). However, the callus formation in the cuttings was studied at regular intervals. The data were analyzed by two-way analyses of variance. Comparisons between the mean values were made by the least significance difference (LSD test) at $P < 0.05$. The SPSS/PC software Ver. 12.0 was used to process all the data.

Diameter of cuttings had significant effect on the shoot and root growth of the teak cuttings. Perusal of data in Table 1 showed that all types of cuttings showed callus formation however, cuttings with diameter less than 20mm failed to root. Diameter class of 30-40 mm had maximum callusing of 93.25 per cent. Conversion rate of callous to roots ranged from 17.90 to 80 per cent in cuttings having diameter of 20-30 mm and 30-40mm, respectively. Cutting size had direct effect on the rooting of the teak cutting in the protected conditions in subtropical conditions of western Himalayas. Dhiman *et al.* (1988) and Bowersox (1970) have reported the significant effect of cutting diameter on the shoot and

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Table 1. Effect of shoot cutting diameter on the shoot and root growth of *Tectona grandis* under polyhouse conditions

Parameters	Diameter class (mm)				SE±	CD (0.05)
	<20	20-30	30-40	>40		
Callusing (%)	70	68.75	93.25	85.75	3.27	7.39
Rooting (%)	0	17.50	80.00	68.00	4.46	10.09
Number of leaves	0	4.75	5.50	8.25	1.19	2.70
Shoot length (cm)	0	5.75	12.50	14.25	1.65	3.74
Root length (cm)	0	4.56	7.25	6.75	1.20	2.81
No. of roots	0	3.00	7.00	7.25	1.14	2.55

Table 2. Correlation among different characters of *Tectona grandis*

Parameters	Callusing (%)	Rooting (%)	No. of leaves	Shoot length (cm)	Root length (cm)	No. of roots
Callusing (%)	1.00	0.910*	0.513	0.839*	0.432	0.378
Rooting (%)	-	1.00	0.613*	0.839*	0.659*	0.532
Number of leaves	-	-	1.00	0.666*	0.420	0.661*
Shoot length	-	-	-	1.00	0.725*	0.549*
Root length	-	-	-	-	1.00	0.236
No. of roots						1.00

root growth of callusing of *Morus alba* and *Populus deltoides*, respectively. Similarily, Husen (2011) reported the enhanced sugar have positive effect on the rooting and imbalance of sugar and auxin affect the rooting in adverse manner in *Tectona grandis*. Maximum number of leaves (8.25) were found in cuttings having diameter of >40mm. However, the cuttings having diameter of 20 to 30mm recorded the lowest number of leaves. Cuttings with 30-40mm diameter registered the maximum root length of 7.25 cm, however, cuttings with diameter >40mm recorded the maximum number of roots (7.25). Callusing, rooting per cent, shoot length, number of leaves, number of roots and root length showed positive correlation (Table 2) among themself. Correlation between callusing and rooting per cent was found to be positive and significant. Shoot length was found significantly correlated with rest of the characters. Rooting per cent had highly significant correlation with callusing, number of leaves, shoot length and root length. The enhanced rooting efficiency is probably due to high sugar content in bigger sized shoot cuttings, and possibly due to increased mobilization of carbohydrates from starch.

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Biomass Production and Carbon Mitigation Potential of Different Shrubs in Urban Landscaping

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Anthropogenic emission of carbon dioxide (CO_2) led to global warming and climate change affecting the biodiversity and destabilizing food and livelihood security (Malhi and Grace, 2000). Global warming risks have increased the need for the identification of ecosystems with high carbon sink capacity as an alternative mitigation strategy of terrestrial carbon sequestration (Kumar *et al.*, 2009). Shrub species play an important role on carbon sequestration in forest and grassland ecosystems. For example, in temperate and subtropical areas, the encroachment of woody species into herbaceous ecosystems has been reported to increase ecosystem carbon sequestration and soil organic carbon probably due to the high productivity (Archer *et al.*, 2001; Brantley and Young, 2010). The biomass of herbs, shrubs, and trees is an important ecosystem attribute for herbivores, their subsequent predators and for ecosystem management as well. For individual trees or forest stands, information on biomass is essential for understanding the changes in energy, carbon, and nutrient flows resulting from changes in forest land use (Brown 1997; Marland *et al.*, 1997; Schimel *et al.*, 2000). Shrub biomass is an important component of the total forest biomass, especially in natural stands. However, compared with arboreal biomass, shrub biomass is often neglected in biomass research because of the lack of methodology and difficulty in calculation. Some research has gone into estimating the biomass of individual shrub species (Paton *et al.*, 2002) but due to lack of reliable shrub data on standing biomass, the net carbon emission estimates for India are highly variable (Ravindernath *et al.*, 1997). Carbon dioxide is captured and stored naturally by the plants through the process of photosynthesis, hence, estimation of this carbon content in vegetation becomes imperative to access the carbon mitigation potential. Considering the thrust area, present investigation was undertaken to quantify the carbon storage in the shrub biomass.

The field study was carried out in the Punjab Agricultural University, Ludhiana during 2012. The experiment site is situated at 30°56' N latitude and 75°52' E longitude with a mean height of 247 meters above the mean sea level. The study was designed to evaluate the carbon mitigation potential in ten different shrub species viz; *Calliandra spp, Ervatamia divaricata, Ervatamia coronaria, Hibiscus rosasinensis, Hamelia patans, Cassia glaucca, Thevetia peruviana, Murraya paniculata, Gardenia jasminoides* and Bougainvillea. The height of shrubs in meters was measured with a long measuring scale. Collar diameter (cm) of all shrubs was measured five cm above the ground level with tree caliper. Canopy spread (m^2) of each shrub was measured with a measuring tape at perpendicular directions i.e., North to South and East to West. Above ground biomass of shrubs by non-destructive estimation was measured by using the standard regression equation for shrub biomass (Thakur *et al.*, 1993). Carbon content in shrubs was calculated by multiplying above ground biomass with 0.4524 as average carbon content in biomass (Chhabra and Dadhwal, 2004) and converted on area scale accordingly.

It is evident from Table 1 that all variables showed statistically significant differences among species for growth of shrubs. The reason of in shrub growth and biomass may be genetic variation and differences in requirements of climatic and site conditions. *Bougainvillea* showed maximum height of 5.10 m and canopy spread of 27.37 m^2 than other shrub species. Maximum collar diameter was observed in *Murraya paniculata* (15.37 cm), which was statistically at par with *Bougainvillea* (14.97 cm) but was significantly different than other species. Telfer (1969) found stem diameter at ground level to be closely related with both leaf and total weight of shrubs.

Above ground biomass also showed significant variation (Table 2). The maximum total above ground dry biomass was recorded in *Murraya paniculata* (12.74 kg shrub^{-1}) i.e., 31.85 t ha^{-1}, which was statistically at par with *Bougainvillea* (12.32 kg shrub^{-1}) i.e., 30.79 t ha^{-1}. However, it was significantly higher than other shrubs. Minimum value for total biomass was observed in *Calliandra spp.* (1.79 kg shrub^{-1}) i.e., 4.28 t ha^{-1}. Similarly, the mean total carbon

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Table 1. Height (m), diameter (cm) and canopy spread (m^2) of different shrub species

Shrub species	Height (m)	Diameter (cm)	Canopy spread (m^2)
Calliandra spp.	1.47	5.43	8.43
Ervatamia divaricata	2.60	10.20	11.30
Ervatamia coronaria	2.90	13.93	8.83
Hibiscus rosasinensis	2.50	7.80	5.53
Hamelia patans	3.40	13.40	9.00
Cassia glaucca	2.73	8.19	9.97
Thevetia peruviana	2.77	6.33	7.40
Murraya paniculata	4.23	15.37	24.70
Bougainvillea	5.10	14.97	27.37
Gardenia jasminoides	3.83	12.10	10.40
CD (0.05)	0.46	0.55	1.40

Table 2. Dry biomass (kg $shrub^{-1}$) and carbon content (kg $shrub^{-1}$) of different shrub species

Shrub species	Above ground biomass (kg $shrub^{-1}$)	Above ground biomass (t ha^{-1})	Carbon content in above ground biomass (kg $shrub^{-1}$)	Carbon content in above ground biomass (t ha^{-1})
Calliandra spp.	1.71	4.28	0.80	1.92
Ervatamia divaricata	5.80	14.50	2.65	6.73
Ervatamia coronaria	10.83	27.07	4.82	12.02
Hibiscus rosasinensis	3.48	8.69	1.59	4.00
Hamelia patans	9.63	24.08	4.49	10.73
Cassia glaucca	3.79	9.47	1.77	4.22
Thevetia peruviana	2.34	5.86	1.37	2.65
Murraya paniculata	12.74	31.85	5.81	14.10
Bougainvillea	12.32	30.79	5.76	13.88
Gardenia jasminoides	8.06	20.16	3.75	9.19
CD (0.05)	0.36	3.92	0.26	0.29

content ranged between 0.80 to 5.81 kg $shrub^{-1}$ with maximum total carbon content in *Murraya paniculata* (5.81 kg $shrub^{-1}$) i.e., 14.10 t ha^{-1}, which was statistically at par with *Bougainvillea* (5.76 kg $shrub^{-1}$) i.e., 13.88 t ha^{-1} and significantly higher than other species. Bilewu (2008) also reported statistically significant difference among shrub species for the amount of carbon being absorbed. Green bush (*Duranta* spp.) absorbed the highest amount of carbon (32.18mg l^{-1} with a range of 25.15 to 40.37 mg l^{-1}). Croton (yellow variegated) absorbed the lowest amount of carbon with a value of 2.84mg l^{-1} on the average (ranging from 0.811 and 4.869 mg l^{-1}). The above ground biomass in bamboo was found as 1.66 t ha^{-1}, whereas, the soil carbon sequestration was found to be 230.32 t ha^{-1} (Dhruba, 2008).

On the basis of research findings, it can be concluded that shrubs help in sequestering a large amount of atmospheric carbon with minimum resource use. These shrubs find their place in all the ecosystems including city landscape. However, the selection of species varies as per the ecosystem suitability and adaptation.

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Indian Journal of Ecology

Differential Seasonal Response to Pre-sowing Treatments by Drupes of *Melia azedarach*

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The seeds having hard seed coat always give delayed and non-uniform germination. The success of nursery depends upon quick and uniform germination of seeds. Longer the germination period shortest will be the growing period available to seedlings, therefore, seeds must germinate within a week or so. Inspite of favourable conditions, many seeds do not germinate and need some pre-sowing treatment (Prasad and Kandya, 1997). This situation is also faced by seeds of *Melia azedarach,* where the seeds are enclosed in a hard shell. *M. azedarach* (dek) is highly valuable species and much popular among the farmers due to its fast growth, adaptability in diverse conditions, compatibility with inter-cultivated crops, market acceptability, etc. Keeping in view the low germination and hard to root nature of the species, a study has been planned with the objective to find out best pre-sowing treatment for these seeds so that maximum and early germination could be obtained.

The seeds collected during the month of January were sown in two different months i.e., February and May, when the atmospheric average monthly temperature is quite low and comparatively high, respectively. Twenty seeds for each treatment with three replications were sown in hyko trays (100cc cup size). These hyko trays were numbered for each treatment and were kept in open. The detail of the treatments is given in Table 1 and 2 for the month of February and May, respectively. The treatments were selected with the objective that most appropriate treatments were continued and rest of the treatments were improved further with some changes.

The data on seed germination, number of seedlings per drupe, height of seedlings, length of main root and number of lateral roots were recorded after three months of sowing. The data on germination was recorded at two days interval to calculate the germination value.

There was a very wide variation in germination of seed when the drupes were given various pre-sowing treatments (Table 1 & 2). In February, maximum seed germination (80.00%) was recorded from the drupes kept in FYM for one week and drupes cut with secateur after keeping seed in FYM for one week. There was no germination in seeds, which were given heat and pressure treatments and 50 per cent sulphuric acid treatment. Drupes were kept in FYM for one week and cut with secateur registered the highest germination value (1.61).

Five treatments in which drupes were kept in FYM in this experiment exhibited significantly higher values for seedling height growth than the control (2.83 cm) but at par among themselves. Maximum height (6.39 cm) was recorded in FYM treatment for one week and drupe cut longitudinally. The minimum value of seedling height (3.25 cm) among the germinated drupes was recorded in sulphuric acid treated drupes, which was at par to untreated drupes. Similar treatment response was recorded for root parameters.

The drupes responded to sulphuric acid treatments during February month, therefore, these treatments were modified during May experiment. Maximum seed germination (70%) was recorded from the drupes treated with concentrated sulphuric acid for 15 minutes and cold water dipping for 24 hours. In control, seed germination was counted upto 31.67 per cent, which was almost similar to the results of February month. There were significant differences for germination among different treatments. Maximum germination value (0.935) and maximum average number of seedlings per drupe (1.97) were also recorded with concentrated sulphuric acid treatment for 15 minutes and cold water dipping for 24 hours. Three treatments, concentrated sulphuric acid treatment for 30 minutes and cold water dipping for 24 hours, concentrated sulphuric acid treatment for 15 minutes followed by cold water dipping for 24 hours and concentrated sulphuric acid treatment for 30 minutes exhibited significantly higher value for height (33.59, 25.29 and 24.18 cm, respectively) than the control (12.34 cm). Concentrated sulphuric acid treatment for 30 minutes and cold water dipping for 24 hours gave maximum values for most of the seedling characteristics like height (33.59 cm), main root (27.42) and number of lateral roots (19.60).

In the present studies, since the experimental

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Table 1. Seed germination and seedling traits after different drupe treatment (February month)

Treatment	Seed germination (%)	Germination value	No. of seedlings per drupe	Seedling height (cm)	Main root length (cm)	No. of lateral roots
Drupes heated upto 1st whistle in pressure cooker	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Drupes heated up for 5 minutes after Ist whistle in pressure cooker	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
50% sulphuric acid treatment for 30 minutes	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Concentrated sulphuric acid treatment for 15 minutes	45.00 (42.10)	0.30	1.98	3.25	7.99	11.10
Dipping in hot water and kept for 48 hours at room temperature	50.00 (44.98)	0.41	1.70	3.66	7.93	12.00
Dipping in hot water and kept for 24 hours at room temperature	70.00 (57.08)	0.80	1.96	3.54	8.17	10.70
Dipping in cold water for 48 hours at room temperature	65.00 (53.91)	0.77	2.25	3.78	6.25	10.20
Dipping in cold water for 24 hours at room temperature	62.50 (52.23)	0.56	2.11	4.01	7.44	11.40
Drupes kept in FYM for two weeks	75.00 (60.09)	1.43	2.62	5.95	10.02	14.30
Drupes kept in FYM for two weeks and cut longitudinally with secateurs	70.00 (57.08)	1.50	1.76	6.15	10.70	15.50
Drupes kept in FYM for one weeks	80.00 (63.58)	1.24	2.39	5.40	9.98	16.10
Drupes kept in FYM for one weeks and cut longitudinally with secateurs	80.00 (63.41)	1.61	1.58	6.39	10.50	13.80
Control (untreated)	30.00 (33.20)	0.16	1.54	2.83	6.98	7.63
CD 5%	9.61	0.23	0.42	1.16	2.79	6.33

* Arc sine transformed values in parentheses

conditions were different during both the months, the drupes pre-sowing treatments exhibited differential responses i.e., in the month of February good response was recorded in FYM treatments, whereas, in the month of May, FYM treatment had no impact, whereas, fairly good response was noticed with sulphuric acid treatment (Table 1 & 2).

The differential response shown by the drupes in the present study to the pre-sowing treatment given during February and May, can be correlated to the external environmental conditions and thus, drupes should be treated accordingly for better germination. One of the requirements for seed germination is a favorable temperature. Although, the seeds of many species can germinate across a wide range of temperatures, others have specific temperature requirements. In any case, germination involves a minimum temperature, an optimum and a maximum temperature. Temperatures below or above are usually lethal and inactivate metabolic activities. The optimum temperature is the temperature at which maximum seeds germinate in a short period and for most of the seeds, this temperature is 15-30°C. The maximum temperature for most of the species is 35-45°C. Species like *Fagus* germinate at temperatures approaching the freezing point, whereas, some species of *Pinus* and *Eucalyptus* in which seeds remain within the fruit bodies until released by fire to colonize burned-over areas (Thompson, 1991). Germination of *Pinus taeda* and *P. echinda* was higher at alternating temperature than at constant temperature of 22°C (Dunlap and Barnett, 1982). The germination study in trees on interaction of temperature and stratification are equally important. Adkins *et al.* (1984) reported that germination of *Abies fraseli* was stimulated by stratification and increasing

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Table 2. Seed germination and seedling traits after different drupe treatment (May month)

Treatment	Seed germination* (%)	Germination value	No. of seedlings per drupe	Seedling height (cm)	Main root length (cm)	No. of lateral roots
Drupes cut longitudinally with secateur and kept in FYM for 30 days	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Drupes kept in FYM for 30 days	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Drupes cut longitudinally with secateur and kept in FYM for 20 days	3.33(6.14)	0.007	1.33	5.25	4.75	5.7
Drupes kept in FYM for 20 days	1.67 (4.31)	0.002	1.00	5.33	6.67	6.3
Concentrated sulphuric acid treatment for 15 minutes and cold water dipping for 24 hours	70.00 (57.21)	0.935	1.97	25.29	16.38	23.4
Concentrated sulphuric acid treatment for 30 minutes and cold water dipping for 24 hours	58.33 (49.87)	0.702	1.64	33.59	19.60	27.4
Concentrated sulphuric acid treatment for 15 minutes	56.67 (48.83)	0.524	1.61	18.97	18.36	17.5
Concentrated sulphuric acid treatment for 30 minutes	65.00 (54.30)	0.759	1.42	24.18	19.33	22.2
Drupes cut longitudinally with secateur	58.33 (49.87)	0.611	1.28	18.62	16.96	24.1
Dipping in cold water for 24 hours at room temperature	33.33 (34.99)	0.177	1.42	9.98	12.04	12.1
Dipping in boiling hot water and kept for 24 hours at room temperature	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
Control (untreated)	31.67 (34.17)	0.156	1.63	12.34	19.09	16.6
CD 5%	11.46	0.278	0.57	9.84	7.40	8.7

* Arc sine transformed values in parentheses

temperature. The germination rates of *Leptospermum scoparium* increased with increasing temperature from 12 to 25°C (Mohan *et al.*, 1984). These various optimum temperatures can be related to the climatic conditions in which these species mature and disseminate their seeds. In the present study also, the external temperature played important role in treatment selection, and a high atmospheric temperature during May did not respond to FYM treatments, where the temperature is still higher than the external temperature. Therefore, the same seed treatment cannot be found suitable in all the conditions but selected as per the prevailing environmental conditions.

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Isolation and Identification of Yeast from Grapes

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Yeast as a versatile model organism approaches us with a vast majority of industrial and medical applications beneficial to human life (Zott *et al.*, 2010). The ability of yeast to convert sugar into ethanol has been harnessed by biotechnology industry to produce ethanol fuel (Barata *et al.*, 2012). The useful physiological properties of yeast have lead to their use in the field of alcoholic beverages, baking, bioremediation, non-alcoholic beverages, nutritional supplements and probiotics (Botstein and Fink, 2011).

The major objectives of the present day study was isolation of different yeasts species from fruits surfaces of grapes, cultural characterization of isolated yeasts, morphological characterization of yeasts and biochemical characterization of yeasts.

Grapes were collected in polythene bags from different locations of Dehradun for the isolation of yeast. The grapes samples were taken to laboratory of Microbiology Department of SBSPGI, Balawala, Dehradun. The samples collected from different locations were subjected to streaking on YEPD (yeast extract peptone dextrose agar) medium using chloramphenicol antibiotic. After maintaining pure culture of yeast, identification was done by employing various morphological and biochemical methods. Morphological methods include gram staining and capsule staining. Biochemical methods are further classified as:

Sugar fermentation test: Yeast fermentation broth is used as an aid in the identification yeast based on fermentation pattern. Most yeast will produce acid and gas as by product of fermentation of certain carbohydrates.

Carbon assimilation test: Basically this test is used for identification of yeast. Yeast uses carbon as a sole substrate for growth. In practical terms, yeast shows growth on carbon assimilation media.

Urease test: Urea is a diamide of carbonic acid. Urease, the enzyme produced by bacteria and fungi, hydrolyses and releases ammonia and carbon dioxide. Ammonia reacts in solution to form ammonium carbonate, which is alkaline leading to an increase in the pH of medium. Phenol red that is incorporated in the medium changes its color from yellow to red in alkaline pH, thus indicating the presence of urease activity.

All the 52 isolates were evaluated and identified morphologically on the basis of colony characteristics. The surface, margin and color of the colonies were observed. The most of the yeast isolates have smooth and mucoid surface while three isolates were having raised and dry surface. Similarly the margins of the yeast colonies were also observed. Most of the isolates have circular margin while irregular margins were also found in some yeast. Colony color is also observed by interpreting the plates. Majority of yeast are giving creamy white color colony where as one yeast is orange in color (Fig.1). Microscopic evaluation is also done by simple staining for yeast identification on the basis of cell shape. All yeast isolates were giving mixed response some are round shaped some isolates are oval in shape and bean pod shape is also observed (Fig.2).

Carbon assimilation test: In the carbon assimilation study, nime sugars were used (glucose, sucrose, lactose, maltose, mannitol, xylose, glycerol, sorbose and fructose). 52 isolates were identified on the basis of assimilation of these sugars (Fig.3). All the 52 isolates were able to utilize glucose as a growth substrate. Sucrose were utilized by most of the isolates i.e., 33 isolates, after glucose. Other carbon sources like sorbose, xylose, and glycerol were utilized by 19, 25 and 30 isolates, respectively. Among all the carbon sources maltose was only to be utilized by maximum 36 isolates. On the other hand, sorbose is utilized by 19 isolates. seven isolates were found, utilizing all of these sugars.

Sugar fermentation test: In the sugar fermentation study, the eight sugars were used (glucose, maltose, sucrose, mannitol, lactose, trehalose, inulin, fructose). 52 isolates were identified on the basis of fermentation by utilization of sugars and the color of medium changes from red to yellow. All the 52 isolates were able to ferment glucose and produce acid. The maltose were utilized by most of the isolates i.e. 44 isolates after glucose. The other sugars

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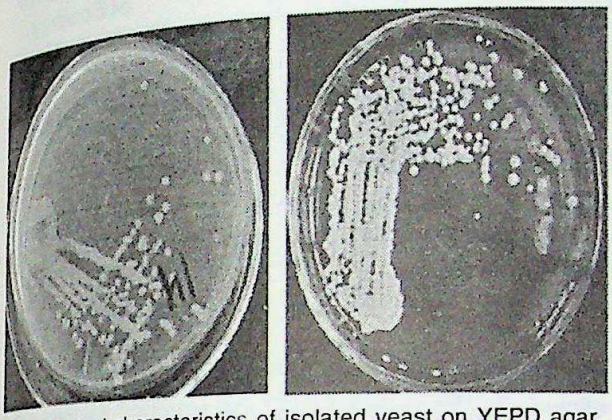

Fig.1. Cultural characteristics of isolated yeast on YEPD agar medium

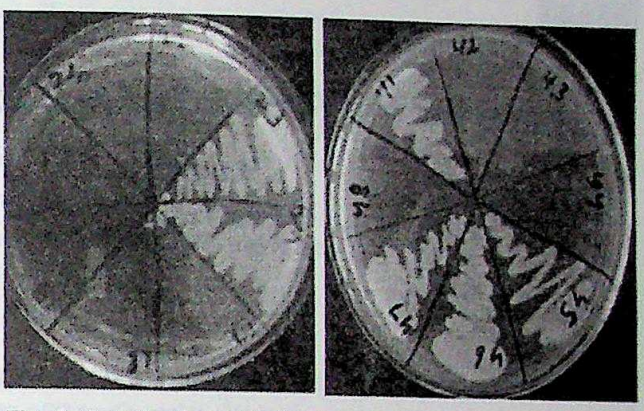

Fig. 3. Growth of yeast isolates on medium containing different sugars as source of carbon

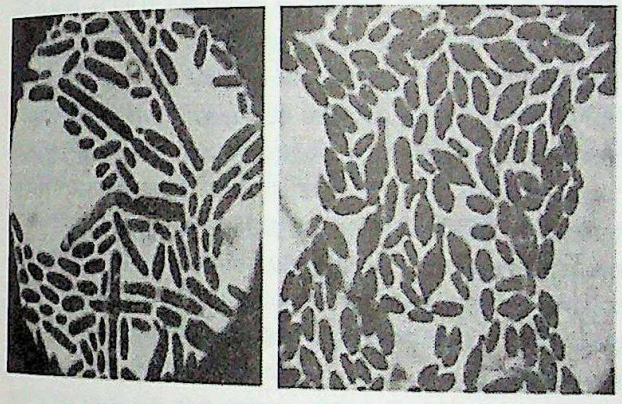

Fig.2. Microscopic features of isolated yeast under 100x

sucrose, trehalose, mannitol and lactose were utilized by 28, 25, 21and 24 isolates, respectively. Among all the sugars, inulin was the only one to be least utilized by isolates i.e., 11 isolates.

Urease test: Urease test is performed to detect the capsule around the yeast cell on the basis of color change from yellow to pink purple (in case of positive). Among 52 isolates, 29 were found positive for urease test i.e., these produces urease enzyme and hydrolyse urea and released ammonia and carbon dioxide.

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Indian Journal of Ecology

A Shield for the Pesticide Applicators : Eco-Friendly Starched Fabric

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The environmental impact of pesticides is often greater than what is intended by those who use them. Over 98 per cent of sprayed insecticides and 95 per cent of herbicides reach a destination other than their target species, including non-target species, air, water, bottom sediments, and food (Miller, 2004). They may cause acute and delayed health effects in those who are exposed. These effects can range from simple irritation of the skin and eyes to more severe effects including damage to the lungs and central nervous system, failures of reproductive organs and dysfunctions of the immune system, endocrine system, and exocrine system, as well as potential cancer risks and birth defects. Exposure of pregnant women to organophosphate pesticides may be associated with decreased gestational age and lower birth weight (Chillymanjaro, 2012).

In general, knowledge of the main determinants of pesticide exposure in developing countries is often poor and also exposure situations may differ among countries. A major factor of pesticide contamination or poisoning in developing countries is the unsafe use or misuse of pesticides. So this study was conducted to protect the unprotected pesticide applicators from the harmful effects of pesticides by giving barrier treatment through an eco-friendly starch to reduce the penetration of pesticides into the fabric.

Selection of materials: Pure white cotton and cotton/ polyester blended fabric with plain weave was procured and its physical properties were examined. Fenvalerate 20 EC was used for the experiment. A barrier treatment was provided to the cotton and cotton/ polyester blended fabric with locally available eco-friendly starch. After spraying the pesticide on fabric given barrier treatment with 10%, 20% and 30% starch solution, the pesticide was stripped with the laboratory grade chemicals, acetone and hexane.

Procedure of work: Thirty test fabric samples measuring 15x15 cm were cut from the scoured fabric. Five (cotton and cotton/ polyester blended fabric each) samples were given barrier treatment with the application of 10%, 20% and 30% starch solution each and allowed to dry. Pesticide spray solution was prepared and applied on all the starched samples. The undisturbed samples were allowed to dry overnight. All the starched samples were laundered i.e., Control – Unlaundered samples, 5% salt water at 50ºC, and 80ºC, 2% detergent at 50ºC and 80ºC.

These samples were separately steeped in salt and heavy duty detergent and separately washed at 50ºC and 80ºC temperatures for one hour each. Later, each sample specimen was rinsed separately in a beaker to avoid cross contamination and dried in sunlight. A solution of hexane: acetone (250:250ml) was prepared. Each sample was separately dipped in separate beaker and the solution was allowed to evaporate till only 5 ml of hexane: acetone was left. The experiment was repeated three times for each condition.

The per cent transmittance was observed for all the samples i.e., their control samples and the samples when washed under different laundering conditions using UV/VIS spectrophotometer (UV 3000+). The more the value of transmittance, the lesser is the pesticide residue left in the sample.

After the samples were treated with 10% starch solution, it was found that the value of transmittance was more in case of cotton samples than the cotton/ polyester blended samples when kept under control (without giving any laundering treatment), laundered with 5% salt water at 50°C and 80ºC, whereas, it was more in case of cotton/ polyester blended samples than cotton when laundered with 2% heavy duty detergent at 50°C and 80°C (Fig. 1). The maximum value of per cent transmittance (64.20%) was observed in the case of 10% starched cotton/polyester blended sample when treated with 2% heavy duty detergent at 80°C. The difference among all the values of transmittance (%) of pesticide residue was significant (CD 0.05). The value of per cent transmittance was more in case of cotton samples when compared with cotton/polyester blended samples in all the laundering treatments i.e., when kept under control (without giving any laundering treatment), laundered with 5% salt water at 50°C and 80°C, 2% heavy duty detergent at 50°C and 80ºC (Fig. 2) when the samples were treated with 20% starch solution. The maximum value of per cent

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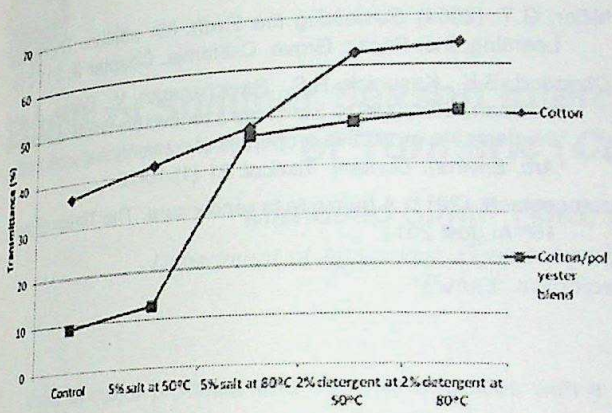

Fig. 1. Comparison of pesticide residue (per cent transmittance) between cotton and cotton/ polyester given barrier treatment with 10% starch solution

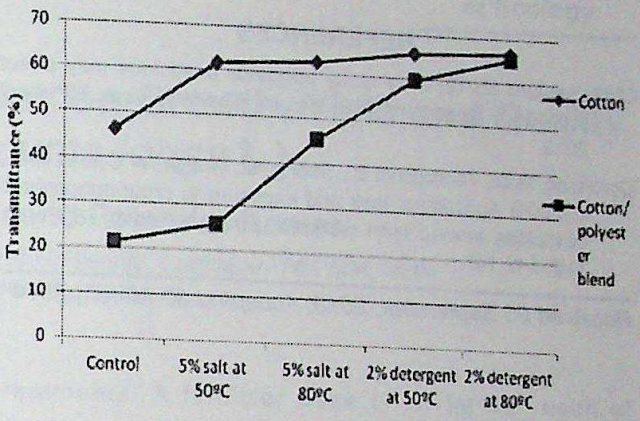

Fig. 2. Comparison of pesticide residue (per cent transmittance) between cotton and cotton/ polyester given barrier treatment with 20% starch solution

transmittance (66.60%) was observed in the case of 20% starched cotton sample when treated with 2% heavy duty detergent at 80ºC. All the values of transmittance (%) of pesticide residue were significant (CD 0.05.05).

After treating the samples with 30% starch solution, it was observed that the value of per cent transmittance was more in case of cotton samples than cotton/polyester blended samples in all the laundering treatments i.e., when kept under control (without giving any laundering treatment), laundered with 5% salt water at 50°C and 80°C, 2% heavy duty detergent at 50°C and 80°C. The maximum value of per cent transmittance (98.40%) was observed in the case of 30% starched cotton sample when treated with 2% heavy duty detergent at 80ºC (Fig 3). All the values of transmittance (%) of pesticide residue were significant (CD 0.05). Regarding the laundering treatments, the value of per cent transmittance was the maximum in case of samples laundered with 2% heavy duty detergent at 80°C in case of both cotton and cotton/polyester blended samples.

A comparison between the two fabrics shows that the maximum value of per cent transmittance was in cotton/

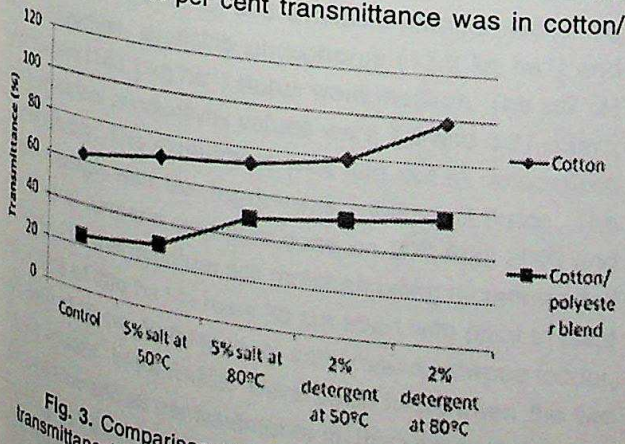

Fig. 3. Comparison of pesticide residue (per cent transmittance) between cotton and cotton/ polyester given barrier treatment with 30% starch solution

polyester blended samples given barrier treatment with 10% starch solution, whereas, in case of cotton fabrics the maximum value of per cent transmittance was found when fabric was given barrier treatment with 20% and 30% starch solution. While comparing the amount of starch, the fabric with barrier treatment with 30% starch solution had maximum per cent transmittance as compared to the samples with 10% and 20 % starch solution.

Thus, the value of per cent transmittance for the amount of barrier treatment (starch) with 30% starch solution had maximum per cent transmittance (98.40%) when laundered with 2% heavy duty detergent at 80ºC for one hour. Obendorf *et al.* (1991) observed that starch act as a pesticide trap, preventing transfer and increasing removal by laundering. The intriguing theory supports that starching effectively reduces the area of contamination on the fabric surface by decreasing pesticide transfer and enhancing pesticide removal.

Exposure to pesticides is one of the most important occupational risks among farmers in developing countries (Coronado *et al.*, 2004). In Punjab, excessive and unregulated use of pesticides since the Green Revolution has led to high cancer and birth defect rates among the farmers. On an average, the use of pesticide by a farmer in Punjab is 923 g ha^{-1} (grams per hectare), whereas, the national average is 570 g ha^{-1} (Sengupta, 2011). With the State indebted to new technologies and a lack of awareness among the population with regard to the use of new agricultural interventions, it is high time to educate the families regarding their protection by altering laundering practices for the clothes contaminated with pesticides and using locally available eco-friendly starch to save the environment.

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Effects of Summer Season Intercrops on Growth, Yield and Quality of Turmeric (*Curcuma longa* L.)

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India is major producer and exporter of spices with a major part of its produce is consumed within the country. Turmeric (*Curcuma longa* L.), an ancient and sacred spice known as 'Indian saffron' is an important commercial spice crop grown in India. It offers good scope in diversification of cereal based cropping system of Punjab. The cultivation of turmeric in the state will not only help to meet its own requirement but will help the country to boost its export. The economy of Punjab state is based on the cereal production. Due to the rise in cost of inputs, it seems probable that the existing cropping pattern of the state may not last long. So there is need to diversify and find alternatives crops for the state. Hence the study on effect of summer season intercrops on growth, yield and quality of turmeric was under taken with an objective to find most efficient intercropping system for higher productivity.

A field experiment was conducted to assess the effect of summer season intercrops on growth, yield and quality of turmeric (*Curcuma longa* L.) in Department of Agronomy, Punjab Agricultural University, Ludhiana, during 2009 -10 and 2010-11.The experimental field is situated at an elevation of 247 m above sea level with geographical co-ordinates at 30° 56'N and 75° 52'E. The soil of experimental field was categorized as loamy-sand typic Ustochrept order and Samana series. The experimental field tested low in organic carbon (0.32 %) and available nitrogen (250.7 kg ha^{-1}). However, available phosphorus (13.8 kg ha^{-1}) and potassium (163.1 kg ha^{-1}) status were medium. The soil pH and electrical conductivity values were 7.3 and 0.21 dSm^{-1}, respectively. The experiment was laid out in randomized block design with ten treatments replicated thrice. The planting of turmeric crop was done on 20th April 2009 and 1st May, 2010 at optimum soil moisture using recommended seed rate of 20q ha^{-1} in rows 30 cm apart with plant to plant spacing of 20 cm. Sathi moong, sathi maize, cowpea fodder, maize fodder, bajra fodder were sown in between the two rows of turmeric as per treatments on the very next day after planting of turmeric in both the years. In mulch treatments, 6.25 tonnes of rice straw was applied for one hectare as mulch immediately after the sowing of crops as per treatments. A fertilizer dose of 25 kg ha^{-1} each of phosphorous and potassium was applied to turmeric at the time of planting. Two weedings were done at 45 and 90 days after planting. The first irrigation was given immediately after planting, subsequently light and frequent irrigations were applied to keep soil moist till the rhizome sprouted. Thereafter, irrigation was applied as per the need of the crop. At maturity the leaves were harvested just near the ground followed by digging of rhizome with the help of spade. Crop was harvested manually on January 30 and 2nd February during 2010 and 2011, respectively and the fresh rhizomes were collected, cleaned and weighed for fresh weight. The sathi moong and sathi maize were harvested on June 25, 2009 and July 5, 2010 and all fodder crops were harvested on June 15, 2009 and 25 June 2010, respectively. The rhizome sample from each plot was taken for analysis of curcumin content. The curcumin content of processed samples was determined using the method described by Thimmaiah (1999).

Yield: A significant reduction in turmeric rhizome yield was observed due to inter-cropping of different summer crops (Table 1). The reduction in yield was more pronounced with inter-cropping of bajra for fodder purpose. Bajra fodder caused 40 % reduction in fresh yield as compared with sole crop of turmeric. The reduction in turmeric rhizome may be due to more aggressive nature of bajra fodder, which competed for the resources at initial stages of the crop and ultimately led to lesser number and weight of rhizome per plant. Likewise inter-cropping of cowpea fodder and maize fodder also caused drastic reduction in rhizome yield as compare to sole crop of turmeric indicating the severity of competition for the resources.

Intercropping of sathi maize with mulch and sathi moong with mulch being at par with each other produced significantly higher dry turmeric yield as compared to turmeric alone (25.77 q ha^{-1}). Mulching in these intercropping treatments is the probable reason for higher turmeric yield over sole crop, indicating its beneficial effects for long duration crops like turmeric. Dry turmeric yield in turmeric + sathi maize with mulch and turmeric + sathi moong+ mulch

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Table 1. Effect of different summer intercrops on growth and yield of turmeric, intercrop yield and net returns (pooled data)

Treatments*	Plant height (cm)	Tillers plant^{-1}	No.of rhizome plant^{-1}	Wt of fresh rhizome plant^{-1} (g)	Turmeric fresh yield (q ha^{-1})	Turmeric dry yield (q ha^{-1})	Intercrop yield (q ha^{-1})	Net Returns (Rs ha^{-1})
T+SMF	39.9	2.06	7.43	86.00	86.41	22.32	3.43	2,48,716
T+SM	37.0	1.48	6.90	77.71	75.99	19.52	3.07	2,18,215
T+SMM	47.5	2.80	10.28	161.00	151.89	39.12	4.33	4,94,536
T+SMZF	35.2	2.03	7.25	90.72	85.06	21.22	5.50	2,19,345
T+SMZ	36.0	1.73	7.01	75.25	80.75	18.48	4.18	1,94,600
T+SMZM	48.3	2.96	10.42	197.53	169.25	44.09	6.88	5,28,061
T+CF	33.3	1.41	6.66	57.61	61.77	15.21	205.04	1,88,661
T+BF	29.7	1.38	5.33	50.11	56.84	14.58	494.60	1,90,375
T+MF	30.5	1.51	6.44	52.37	72.48	15.68	365.03	1,85,491
ST	36.4	1.75	6.68	107.21	94.80	25.77		3,44,875
C D (p=0.05)	7.35	0.43	1.46	8.82	22.86	5.43		

*T+SMF= turmeric + one row of sathi moong with recommended fertilizer to sathi moong, T+SM= turmeric + one row of sathi moong with no fertilizer to sathi moong, T+SMM= turmeric + one row of sathi moong with mulch, T+SMZF= turmeric + one row of sathi maize with recommended fertillzer to sathi maize, T+SMZ= turmeric + one row of sathi maize with no fertilizer to sathi maize, T+SMZM= turmeric + one row of sathi maize with mulch, T+CF= turmeric + one row of cowpea fodder, T+BF= turmeric + one row of bajra fodder, T+MF= turmeric + one row of maize fodder and ST= sole turmeric

was 41.5 and 34% higher than sole turmeric. The increase in yield might be due to the beneficial effect of mulch. Similar trend was observed in fresh rhizome yield of turmeric. The results indicated that intercropping of summer crops like sathi moong and sathi maize without fertilizer to intercrops maize fodder, bajra fodder and cowpea fodder in turmeric reduced the dry turmeric yield significantly. The reduction in yield attributed to less number and weight of rhizome per plant as a result of intercrops of summer crops. The application of recommended fertilizers to sathi moong and sathi maize had increased the grain yield of intercrops.

Yield attributes: Sole crop of turmeric showed significantly less yield attribute values as compared to mulched inter crop treatments. Different summer inter-crops without mulching significantly reduced the yield attributing characters of turmeric. The maximum plant height of 48.3 cm was recorded when turmeric was inter-cropped with sathi maize with mulch, which was at par when turmeric was inter-cropped with sathi moong with mulch (47.5 cm). It might be due to beneficial effect of mulch. These results were in accordance with the findings of Gill *et al.* (1999). The lowest plant height of 29.7 cm was observed when turmeric was intercropped with bajra fodder, which might be due to more exhaustive nature of bajra fodder for nutrient removal. The practice of mulching resulted in more number of leaves per plant (10.55 and 10.11) when turmeric was inter-cropped with sathi maize and sathi moong with mulch, respectively, which was significantly better than sole crop of turmeric. Similarly, number of rhizome per plant and weight of rhizome per plant were significantly better in mulch treated plots than sole crop as well as rest of the treatment. Similar results were obtained by Manhas (2009) and Verma and Samaik (2009).

Quality: The curcumin content ranged from 2.81 to 2.88 per cent under different treatments. However, the differences in the curcumin content of turmeric under different intercrop treatments were found non-significant when compared with sole turmeric (2.84 %). The quality of turmeric in term of curcumin content was not influenced with different intercrops, since, curcumin content is inherent character of turmeric, which could be the probable reason for non-significant effects.

Economics: Intercropping of sathi maize with mulch and sathi moong with mulch enhanced the net returns as compare to sole crop of turmeric. Inter-cropping with sathi maize with mulch, sathi moong with mulch resulted in higher net return Rs. 5,28,061, 4,94,536 per hectare than the sole crop, respectively. Minimum net return occurred from turmeric + maize fodder. Turmeric + sathi moong and turmeric + sathi maize both with recommended fertilizer gave net return of Rs. 2,48,716 and Rs. 2,19,345 per hectare, respectively, the net return was comprehensively decreased without recommended fertilizer.

The present study revealed that turmeric can be successfully inter-cropped with sathi maize and sathi moong with mulch for higher total productivity and profitability. The practice of mulching with summer intercrops in turmeric has

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proved its beneficial effects for enhancing the productivity of the intercropping system. Therefore, it would be an important alternative for farmers for diversification, resource conservation efficiency, productivity and higher income.

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Response of Clusterbean [*Cyamopsis tetragonoloba* (L.)] to Growth Substances in Sub-tropical Climate of Rajasthan

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Guar [*Cyamopsis tetragonoloba* (L) Taub] is a drought tolerant summer annual legume. Being a deep rooted and drought hardy, clusterbean has occupied large areas in arid and semiarid tracts. This crop is mainly grown in Rajasthan, Gujarat, Haryana, Punjab and Uttar Pradesh. Rajasthan ranks first in respect of both area and production, occupying an area of 30.94 lakhs ha and production of 18.47 lakhs ton during 2011-12 (ASDA, 2013). Unlike the seeds of other legumes, guar seed contains sufficient amount of galactomannan gum, which form a viscous gel in cold water. Guar gum has 5-8 times the thickening power of starch. It is used in textile, paper manufacture, stamps, cosmetics, pharmaceuticals, food products, like bakery products, ice cream, stabilizer for cheeses and meat binder. Also, it is used in oil wells, mining industries, explosives, and other industrial applications (Undersander *et al.*, 2006). On the other hand, guar is considered as an excellent soil improvement crop, like other legumes, with respect to available nitrogen, which improve yield of succeeding crops. Several researchers working on different crop have reported that the use of growth substances is one of the effective means of delaying the senescence of leaves as well as retarding the abscission of reproductive organs. Application of growth regulator also increase flower, fruit setting, grain filling and test weight in different crops. The use of agro-chemicals have been started to modify various metabolic or physiological processes to regulate plant growth. Several researchers working on different crop have reported that the use of growth substances is one of the effective means of delaying the senescence of leaves as well as retarding the abscission of reproductive organs. Application of growth regulator also increase flower, fruit setting, grain filling and test weight in different crops (Patel and Singh, 1980).

An experiment was conducted at the Department of Agronomy, Rajasthan College Agriculture, Udaipur during *kharif* seasons. Twenty eight treatment combinations i.e. four varieties (RGC-936, RGC-1002, RGC-1003 and RGC-1017) as main plot treatment and seven growth substances (control, seed treatment with thiourea 500 ppm, foliar application of thiourea 500 ppm, Seed + foliar application of thiourea 500 ppm, Seed treatment with TGA 100 ppm, foliar application of TGA 100 ppm and Seed + foliar application of TGA 100 ppm) as sub-plot treatment were laid out in split-plot design with three replications. The soil of the experimental site was clay loam in texture having 250.12 kg ha^{-1} alkaline permanganate oxidizable N (Subbiah and Asija, 1956), 17.04 kg ha^{-1} available P (Olsen *et al.* 1954), 340.24 kg ha^{-1} 1 N ammonium acetate exchangeable K (Stanford and English 1949) and 1.17% organic carbon (Jackson, 1973). The pH of soil was 7.6 (1:2.5 soil and water ratio) and bulk density recorded 1.46 Mg m^{-3} in 0-30 cm soil depth

Effect of cultivars: Plant population of clusterbean recorded at 30 DAS and at harvest were not affected significantly due to varieties. Plant height/plant are the genetic characters and hence, different cultivars varied with respect to these characters, which ultimately brought about variation in dry matter accumulation (Table 1). Variety RGC-936 recorded significantly higher plant height at harvest and dry matter accumulation at all the growth stages as compared to other varieties exceppt RGC-1017, which was statistically at par with RGC-936. This might be due to fast growth habit of variety RGC-936 and RGC-1017, which continuously increased in height, dry matter accumulation and also took less time to mature than RGC-1017, RGC-1003 and RGC-1002. Further the differential behaviour among the varieties could be explained solely by the variation in their genetic make up and their differential behaviour under different conditions. This may be because of the long duration and fast later growth of these cultivars and it was also evident by significantly higher crop growth rate at later stages of growth. Similar results were also reported Meena *et al.* (2013).

Effect of growth substances: Seed treatment + foliar spray of thiourea and thioglycolic acid applied at initiation of branches and flowering stages brought about significant improvement in growth parameters during two years of experimentation. Seed treatment + foliar spray of 500 ppm of thiourea recorded significantly higher value of growth attributes of clusterbean crop but this treatment was

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Table 1. Effect of varieties and growth substances on plant population and plant height of clusterbean (pooled data of 2 years)

Treatment	Plant population (lakh ha^{-1})		Plant height (cm)	Dry matter accumulation (g plant^{-1})			
	30 DAS	At harvest	At harvest	30 DAS	45 DAS	60 DAS	At harvest
Varieties							
RGC 936	3.17	2.83	93.69	3.55	10.74	48.69	64.28
RGC 1002	2.93	2.62	85.75	2.79	8.76	39.05	56.65
RGC 1003	3.08	2.67	86.48	2.96	9.26	41.53	58.20
RGC 1017	3.15	2.77	90.78	3.46	10.56	47.45	62.47
CD (P=0.05)	NS	NS	2.76	0.12	0.55	2.37	2.31
Growth substances							
Control (Water spray)	2.99	2.67	79.79	2.22	6.97	30.84	49.70
Seed treatment thiourea 500 ppm	3.05	2.70	83.72	2.64	8.26	36.97	55.40
Foliar application of thiourea 500ppm	3.11	2.74	91.79	3.34	10.43	46.55	61.64
Seed + foliar application of thiourea (500ppm each)	3.16	2.77	96.83	4.07	12.45	55.99	67.76
Seed treatment TGA 100ppm	3.08	2.72	89.49	3.12	9.60	43.23	61.16
Foliar application of TGA 100ppm	3.06	2.69	86.82	2.99	9.04	41.19	60.32
Seed + foliar application of TGA (100ppm each)	3.15	2.76	95.78	3.94	12.05	54.50	66.81
CD (P=0.05)	NS	NS	2.03	0.11	0.44	1.69	2.23

statistically at par with 100 ppm thioglycolic acid. It may also be noted that not only accumulation of dry matter was increased due to the effects of thiourea and thioglycolic acid spray, but translocation of dry matter as well as its efficiency were also found to be higher in crop plants sprayed with thiourea and thioglycolic acid as compared to unsprayed crop (Table 1). Thus, improvement in plant height and dry matter accumulation is sufficient to indicate that dry matter partitioning was favorably influenced by thiourea and thioglycolic acid spray. The growth attributes increased under foliar as well as thiourea and thioglycolic acid may be attributed to the better availability of nutrients. In the light of these observations, it is fairly conceived that thiourea might have stimulated the photosynthetic carbon fixation mechanism and hence might have increased canopy photosynthesis. Significant increase in dry matter accumulation obtained with thiourea treatment provide ample support to such effects.

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Effect of On-farm Nutrient Sources on Organic Maize Productivity and Soil Health

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The aim of nutrient management in organic systems is to optimize the use of on-farm sources and minimize losses (Kopke, 1995), and the emphasis is stressed on the use of on-farm inputs rather the off-farm inputs. The philosophy is to feed the soil rather than the crops to maintain the soil health and it means giving back to the nature what has been taken from it (Funtilana, 1990). Organic farming is practiced with in crops, which have either low nutrient requirements or are more responsive to application of organic manures and maize crop highly suits to this aspect on account as its response to organic source of nutrition. The research investiations revealed that the productivity of a crop is controlled by many factors of which the mineral nutrition especially of nitrogen is of prime significance. The availability of organic manures is limited so the other available options for organic nutrition management are crop residue recycling and vermicompost. Cereal crop residues on an average retain 25% of N and P, 50% of S and 75% of K of their total uptake (Prihar *et al.*, 2000). The present investigation was aimed at studying the nutrient supplying potential of different on-farm organic sources and their combination to maize and soil health.

The field experiment was conducted on maize in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L. emend Fiori & Paol.) cropping system at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana on a sandy loam soil in a randomized block design. The soil of experiment site was low in organic carbon (0.33%) having 240.0, 35.1 and 135.4 kg ha^{-1} available (alkaline permanganate oxidisable) nitrogen, phosphorus (0.5 M $NaHCO_3$ extractable) and potassium (1 M ammonium acetate exchangeable), respectively. On-farm organic sources used were farmyard manure (FYM), wheat residues (WR), vermicompost (VC) and combination of FYM, WR and VC in equal proportion. Green manuring with sunnhemp (*Crotalaria juncea* L.) was done in all the plots and the organic sources were used to supply half of the recommended 125 kg N ha^{-1}. The quantity of organic sources was applied on the basis of the respective nitrogen content of organic source. The average N, P and K contents on dry weight basis in FYM, VC, wheat straw and sunnhemp were 0.81, 0.80, 1.40; 1.25, 0.46, 1.25; 0.41, 0.17, 1.40 and 2.10, 0.4, 1.53, respectively. Maize hybrid cv. *Paras* was sown as per recommended practices. The maize was followed by wheat which received 10 t FYM, 6 t crop residue and 150 kg rock phosphate ha^{-1}. The average dry mass of green manure crop was 3.50 t ha^{-1}. The insect-pest management in maize was done by using *Trichogramma*-cards @ 100 cards ha^{-1} as one time application after 15 days of sowing. The data on different crop and soil parameters for two years were pooled.

Effect on soil properties: Soil organic carbon was highest with FYM and it was statistically at par with combination of nutrient sources but was significantly better than WR, VC and unfertilized control. WR and VC were statistically at par with each other. Meelu *et al.* (1994) also reported improvement in soil health with application of crop residues. Soil chemical properties except EC were influenced significantly after four crop cycles. All the nutrient sources had significantly lower pH than the unfertilized control. FYM had significantly lower pH than WR and combination of nutrient sources but was statistically at par with VC. The highest available N was with FYM and it was statistically at par with WR and combination of nutrient sources but was significantly higher than the VC. The highest available P was with combination of nutrient sources and it was statistically at par with all the other sources and significantly better than the unfertilized control. The highest available K was with WR and it was statistically at par with FYM and combination of nutrient sources but was significantly better than VC and unfertilized control.

Growth and yield of maize: The highest mean grain yield of maize (42.6 q ha^{-1}) was obtained with combined application of FYM, WR and VC and it was statistically at par with FYM and VC applications alone. Crop residue gave significantly lower grain yield than all the other sources of nutrition but was significantly better than the unfertilized control (Table 1). The poor grain yield with crop residue might be due to immobilization of available and applied nutrients, whereas, FYM, VC and combination of FYM+WR+VC might have supplied nutrients in a sustained manner. Yadav *et al.* (2013) and Davari and Sharma (2010) also reported similar seed yields of crops with FYM and vermicompost. Beri *et al.* (1995) reported reduction in grain

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Table 1. *Growth, yield attributing characters, grain yield of maize and soil health as affected by different sources of nutrition*

Treatment	Crop growth and yield (Pooled data)							Soil health after 4 crop cycles				
	Plant height (cm)	Cob length (cm)	Cob diameter (cm)	Grain rows cob^{-1}	Grains Cob^{-1}	Thousand grain weight (g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	pH	EC (dSm^{-1})	Available nutrients (kg ha^{-1})			OC (%)
											N	P	K	
FYM	186.4	18.0	4.1	12.2	336.9	306.0	40.7	96.2	7.10	0.144	280.8	62.4	179.2	0.723
WR	173.6	17.3	4.1	11.9	338.9	283.2	34.1	80.7	7.33	0.147	238.9	63.6	184.8	0.566
VC	195.0	18.2	4.3	12.5	325.9	326.2	42.1	94.0	7.27	0.150	212.1	58.1	154.9	0.537
FYM+WR+VC	190.6	18.5	4.1	12.2	363.8	314.9	42.6	95.8	7.33	0.175	268.8	66.9	168.0	0.666
Control	143.3	15.1	3.9	11.5	280.3	254.6	17.8	42.5	7.57	0.218	179.6	34.0	112.0	0.283
CD(P=0.05)	22.3	1.2	NS	0.4	42.7	28.5	4.4	13.2	0.23	NS	54.6	13.2	28.9	0.100

yields with incorporation of crop residues. The stover yield also observed the similar trend as that of grain yield.

The mean plant height at maturity, cob length and grains cob^{-1} did not vary significantly among different nutrient sources but all the nutrient sources were significantly better than unfertilized control. Cob diameter was not influenced significantly with different treatments. Thousand grain weight was highest with VC and it was statistically at with FYM and combination of nutrient sources but was significantly better than the WR and unfertilized control. WR was statistically at par with FYM and significantly better than unfertilized control. Aulakh *et al.* (2013) reported statistically similar yields of maize when grown with organic nutrition sources and chemical fertilizers, whereas, Walia and Kler (2005) reported higher grain yield of organically grown maize than that under inorganic system after five crop cycles.

Organic maize, thus, can be grown by using FYM, vermicompost or combination of FYM+vermicompost+wheat residue but soil organic improvement is highest with use of FYM alone.

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Effect of Spacing on Growth, Yield and Quality of Guava cv. Sardar

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High density orcharding system is a very intensive form of fruit production with great relevance to the food and nutritional prosperity of the ever increasing human population. There are several advantages of high density planting (HDP) such as early production, high returns per ha, efficient use of fertilizers and irrigation water. Spacing of the plants in the system depends on fertility of the soil, availability of water, intensity of sunlight and wind exposure, which will affect growth parameters in guava (Singh, 2008). It differs in many ways from the traditional technology involving system of fruit growing which accommodates a few but large sized trees per unit land area. Such conventional orchards, although require low establishment cost, involve less labour efficiency and incur higher production expenses per unit area of production. They also need longer duration to start giving economical yields and have low and irregular production of fruits. Besides, fruit quality is also affected due to meager sunlight penetration into the dense canopies and the large sized trees pose difficulties in orchard management practices. High density orchards on the other hand, accommodates more of plants per hectare, and are easier/safer to manage, leading to reduced cost of production in the long run. It is a intensive technology, which requires more capital to establish and trees must be precocious with high regular yields to be highly profitable. The technology HDP needs to be tested and fine tuned to the regions of its cultivation under tropical ecosystem of South India including guava growing areas of Karnataka.

The present investigation was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi (University of Horticultural Sciences, Bagalkot), Gokak taluk of Belgaum district, Karnataka during 2012-2013. In present investigation, five different spacing (2x1, 3x1.5, 3x3, 6x3 and 6x6m), were used and observations on growth, yield and quality were recorded at monthly interval in randomly selected uniform healthy plants. The experiment was conducted in Randomized block design (RBD) wth three replications.

The plant height was significantly higher with wider spacing as compared to closer spacing. The plants at 6 x 3 m registered significantly highest plant height of 1.78, 1.87, 1.94, and 2.03 m at 2, 3, 4 and 5 MAP (months after pruning), respectively (Table 1). This was followed by plants accommodated at 3 x 3 m and 6 x 6 m spacing at different months of its growth (Table1). Increase in plant height under wider spacing may be due to the vigorous growth in wider spacing as a result of less competition for light, water and nutrition. Further the plantation was in its initial years of growth and establishment as such has shown higher plant height. Similar findings were reported by Bal and Dhaliwal (2003) Singh and Channana (2005) who got higher plant height at 6 x 6 m spacing compared to 6 x 4 and 6 x 5 m spacing in guava. Contrary, Kundu (2007) reported that the increase in plant density markedly increase the plant height in guava cv. Sardar.

Among the different spacing treatments the plants with

Table 1. Effect of different spacing on plant height (m) in guava cv. Sardar

Spacing	Months after pruning (MAP)				
	1	2	3	4	5
2 x 1 m	1.43	1.57	1.66	1.74	1.80
3 x 1.5 m	1.47	1.58	1.67	1.75	1.82
3 x 3 m	1.63	1.71	1.78	1.85	1.90
6 x 3 m	1.61	1.78	1.87	1.94	2.03
6 x 6 m	1.61	1.72	1.84	1.94	2.02
C D at 5%	0.13	0.14	0.16	0.17	0.17

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Table 2. Effect of different spacing on number of secondary and tertiary branches in guava cv. Sardar

Spacing	Number of secondary branches (Number of tertiary branches)					North - South (East - West)				
	Months after pruning (MAP)					Months after pruning (MAP)				
	1	2	3	4	5	1	2	3	4	5
2 x 1 m	10.49 (19.46)	12.64 (25.11)	15.32 (26.99)	16.81 (30.12)	18.46 (33.66)	1.12 (1.14)	1.34 (1.35)	1.42 (1.39)	1.48 (1.47)	1.53 (1.53)
3 x 1.5 m	7.75 (15.57)	11.75 (22.07)	15.80 (24.57)	18.32 (27.43)*	19.62 (30.29)	1.26 (1.19)	1.43 (1.46)	1.49 (1.50)	1.54 (1.55)	1.60 (1.61)
3 x 3 m	8.39 (17.89)	13.93 (25.23)	16.88 (26.68)	18.43 (29.83)	18.75 (33.86)	1.59 (1.52)	1.75 (1.62)	1.81 (1.64)	1.85 (1.78)	1.95 (1.83)
6 x 3 m	8.75 (19.00)	14.83 (27.25)	16.79 (30.17)	19.28 (34.00)	19.75 (36.50)	1.46 (1.43)	1.64 (1.55)	1.69 (1.61)	1.73 (1.69)	1.79 (1.75)
6 x 6 m	8.94 (17.84)	12.18 (24.31)	13.71 (26.81)	16.64 (30.77)	18.01 (34.02)	1.25 (1.32)	1.37 (1.49)	1.44 (1.54)	1.50 (1.58)	1.55 (1.63)
C D at 5%	NS (NS)	NS (NS)	NS (NS)	1.92 (3.92)	1.16 (3.63)	0.15 (0.20)	0.21 (0.26)	0.20 (0.18)	0.20 (0.18)	0.21 (0.18)

wider spacing recorded highest number of secondary and tertiary branches compared to closer spacing. The plants at 6 x 3 m registered significantly maximum number of secondary and tertiary branches and was at par with 3 x 3 m spacing (Table 2). Increase in number of secondary and tertiary branches in wider spacing may be due to availability of both spatial and floor space resulting in less competition between the plants for light, nutrition and water. Therefore, plant under spacing of 6 x 3 and 3 x 3 m putts up more vigorous growth producing higher number of secondary and tertiary branches. These results are in agreement Bal and Dhaliwal (2003) who reported wider canopy spread in plants with wider spacing.

The plants with intermediate spacing of 3 x 3 m recorded higher canopy spread in both North- South and East-West directions compared to other spacing. This was found on par with plants at 6 x 3 m spacing (Table 2). Higher canopy spread in intermediate spacing may be due to availability of sufficient space for canopy spread in the initial stages of establishment. In the present investigation also the plants are of 3 years old and are in the initial stages of establishment. Bal and Dhaliwal (2003) found maximum canopy spread (N-S and E-W) in plants spaced at 6 x 6 m, but Kundu (2007) was of opinion that increased in plant density showed decreased canopy spread in guava cv. L-49.

The results on fruit set revealed that plants at intermediate spacing of 3 x 3 and 3 x 1.5 m produced significantly higher number of flowers and their by set maximum number of fruits as depicted by higher percentage of fruit setting (Table 3). Higher flowering and fruit setting may be attributed to production of optimum number of flower and fruit bearing tertiary shoots (Table 2) in plants under the above population density. Further at 3 x 3 and 3 x 1.5 m spacing the light penetration in to the canopy was also optimum for better initiation of flower and higher fruit setting. Investigations also revealed significantly highest number of fruits per plant (43.31) at 3 x 3 m, which was at par with 3 x 1.5 m. Similar results were found by Bal and Dhaliwal (2003) and Gorakhsingh (2007) in guava. In the present investigation, significantly highest yield per ha were noted in plants at closer spacing due to higher yielding ability per

Table 3. Effect of different spacing on yield and quality parameters during mrig bahar in guava cv. Sardar

Spacing	Per cent fruit set	No. of fruit set plant^{-1}	Number of fruits harvested plant^{-1}	Yield (tons ha^{-1})	TSS(°B)	Ascorbic acid (mg 100 g^{-1})
2 x 1 m	80.96	36.18	34.23	34.93	13.25	119.78
3 x 1.5 m	85.63	45.18	42.98	19.98	13.73	133.33
3 x 3 m	85.45	45.74	43.31	9.90	12.10	156.18
6 x 3 m	81.18	38.59	36.92	4.26	12.25	178.83
6 x 6 m	74.25	27.26	25.83	1.50	13.24	227.50
C. D. at 5%	6.97	11.48	10.97	5.84	0.71	7.81

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unit area occupied.

The quality parameters like TSS and ascorbic acid content in fruits recorded significant changes with planting densities. But contrary to present investigation Kundu (2007), Bal and Dhaliwal (2003) reported that fruits from wider spacing had superior quality parameters to closer spacing in well established guava plantation. The results are in agreement with those of Ajithpal and Dhaliwal (2004) who reported that plants under 6 x 6 m and 6 x 4 m spacing produced fruits with high vitamin C content due to interception of more radiation in the canopy. Similar results were also reported by Gorakhsingh (2007) in guava.

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Evaluation of Moisture and Moisture Retention Capacity of Castor (*Ricinus communis* L.) in Different Storage Duration

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Castor (*Ricinus communis*) is the primary host plant of Eri silkworm, *Samia ricini* Boisd and widely distributed and cultivated as oilseed. The silkworm is polyphagous and feeds on the leaves of different food plants and castor is the most preferred food plants compared to others rearing of eri silkworm. Quality and quantity of food as well as the highly nutritious and nutrient balanced foods play an important role in the survival, longevity, distribution, reproduction, healthy growth and development of any insect (Purohit and Pavankumar, 1996; Prasad, 2009). Nutrition is the most important physiological factors, which is derived from the host plant leaf (Sundar Raj *et al.*, 2000). So better the quality of leaves greater would be quality of cocoons. The nutritional parameters like moisture and moisture retention capacity plays major role in keeping the preserved host plant leaves fresh till they are consumed by the silkworm. Duration of storage, temperature, humidity, light, aeration, quality of leaves or shoots in a given space (density of storing) and many other conditions greatly influence the quality of leaves. The present study deals with an attempt to see the changes in moisture and moisture retention capacity of castor leaves in different storage duration for effective utilization in eri silkworm rearing.

The present study was carried out at Assam Agricultural University, Jorhat, during autumn and spring season 2010-11. According to the method suggested by Muniraju *et al.* (1999), the tender, medium and mature leaves of castor were harvested separately in the morning hours and heaped on mat with wet gunny cloth covering for 24 hours. Moisture and moisture retention capacity were determined on dry weight basis by the method suggested by Ninge Gowda and Sudhakar (2002). One hundred fresh leaves comprising of tender, medium and mature leaves weighed immediately after harvested. They were then kept at room temperature weighed again after 4, 8, 12 and 24 hours. The leaves were then dried in hot air oven at 60°C for 48 hours for the dry weight and moisture retention capacity.

The leaf storage had significant effect on nutrient contents of castor leaves (Table 1). The moisture content was found in decreasing trend and had significant effect with the maturity of the leaves (79.60-76.85%). During spring, the moisture content in fresh leaves was maximum (81.01%), which was significantly higher than the autumn (74.96%) season leaves. The moisture retention capacity (%) exhibited decreasing trend with the maturity of leaves (91.01-88.64%) as well as with the advancement of storage duration. After 4 hours, moisture retention capacity was highest in tender leaves (91.01%), being significantly more than the medium and mature leaves and the lowest value was recorded after 24 hours (68.10%). Significantly, the moisture retention capacity was observed maximum in spring season than the autumn and decreased gradually

Table 1. Moisture and moisture retention capacity of castor leaf in different storage duration

Factor	Moisture content (%)	Moisture retention capacity (%)			
		4 Hr	8 Hr	12 Hr	24 Hr
Leaf type					
Tender	79.60	91.01	86.97	81.40	78.30
Medium	77.50	89.12	86.11	79.81	69.63
Mature	76.85	88.64	84.34	76.67	68.10
CD (5%)	4.64	4.24	4.31	7.83	5.02
Season					
Spring	81.01	93.28	88.75	84.00	78.31
Autumn	74.96	91.24	87.05	82.25	75.80
CD (5%)	7.72	7.73	6.51	6.97	6.12

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with the increasing storage duration. In both the seasons, it was found highest after 4 hours and the lowest after 24 hours of storage duration. The results are in conformity with the findings of Mir *et al.* (2012).

The present study indicates that storage of leaf considerably decreased moisture and moisture retention capacity. Therefore, during preservation of castor leaves, care has to be taken to minimize moisture loss of leaves to maintain quality and healthy growth and development of eri silkworm.

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Synthesis and Antifungal Evaluation of N-Benzylidenenaphthalen - 1-amines

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Carbon-nitrogen double bond is widely distributed in nature, in the form of biological compounds which are important for the vital metabolism of the living organisms and in various synthetic compounds of pharmaceutical and agricultural importance. N-substituted imines, also known as Schiff bases were first reported by Hugo Schiff in 1864. The synthesis and assaying of bio-potential of imines have received considerable interest in past decades (Chen and Brown, 2000). The imines, due to the presence of carbon-nitrogen double bond in their molecules, provide a potential site for both chemical and biological activity (Matharu *et al.*, 2005; Khera *et al.*, 2005). The nature of substitutes, its position in the phenyl ring and the extent of conjugation play a vital role in determining the chemical and biological behaviour of the compound, which is required to overcome the increasing fungal infestations and growing resistance in pathogens (Annapoorni and Krishnan, 2011; Rai *et al.*, 2006; Sandhar *et al.*, 2006a; Gupta *et al.*, 2012). The new combinations are needed to be synthesized. The present work involves the synthesis of novel series of imines by condensing naphthalen-1-amine with respective aryl aldehydes and their antifungal evaluation against various phytopathogenic fungi.

Melting points were taken in open capillaries in an electric melting point apparatus and were uncorrected. Purity of the compound was checked by TLC. Infrared spectra were recorded on a Perkin Elmer FT-IR spectrometer using KBr discs. Proton Nuclear Magnetic Resonance spectra and ^{13}C Nuclear Magnetic Resonance spectra were recorded on a Bruker Avance II 400 NMR spectrometer in $CDCl_3$ with TMS as internal solvent. Mass spectra were recorded on Waters LC-MS-MS Quattro Micro™ API. Elemental analysis (C,H,N) were recorded on Thermo Scientific Elemental Analyser for CHN.

Synthesis of N-benzylidenenaphthalen-1-amines: Benzaldehyde (I) (0.25 mol) and naphthalen-1-amine (0.25 mol) were dissolved in 10 ml of ethanol in a round bottom flask. The mixture was refluxed until a clear solution was obtained. The clear solution was cooled to get the crude solid. This crude product was then recrystallized from ethanol to obtain N-benzylidenenaphthalen-1-amine (Ia). Reaction of naphthalen-1-amine with 2-nitrobenzaldehyde (II), 3-nitrobenzaldehyde (III), 4-nitrobenzaldehyde (IV), 4-methoxybenzaldehyde (V), 3,4-dimethoxybenzaldehyde (VI), 3,4,5-trimethoxybenzaldehyde (VII), 2-hydroxybenzaldehyde (VIII), 3-hydroxybenzaldehyde (IX) and 4-hydroxybenzaldehyde (X) was carried out by above procedure to give N-(2-nitrobenzylidene) naphthalen-1-amine (IIa), N-(3-nitrobenzylidene) naphthalen-1-amine (IIIa), N-(4-nitrobenzylidene) naphthalen-1-amine (IVa), N-(4-methoxybenzylidene) naphthalen-1-amine (Va), N-(3,4-dimethoxybenzylidene) naphthalen-1-amine (VIa), N-(3,4,5-trimethoxybenzylidene) naphthalen-1-amine (VIIa), N-(2-hydroxybenzylidene) naphthalen-1-amine (VIIIa), N-(3-hydroxybenzylidene) naphthalen-1-amine (IXa) and N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa), respectively.

In *vitro* screening for antifungal potential: Each compound (20 mg) was dissolved in 1 ml Tween 20 (Polyoxyethylene sorbitan) and 9 ml sterilized distilled water to prepare stock solution of 2000µg ml^{-1}. The stock solution was serially diluted to obtain the required concentrations of 1000, 500, 250, 100, 50 and 25 µg ml^{-1} of the test compounds. Cavity slides were used for studying the antifungal activity. The spore suspension of test fungi was prepared in sterilised distilled water to from fresh spores of *Ustilago hordei, Bipolaris sorokiniana and Puccinia striiformis.* Suspension was filtered through three layers of sterilised cheese cloth in order to remove mycelial particles under aseptic conditions. Haemocytometer was used to form standardized spore suspension (1 x 10^6 spores ml^{-1}). Small droplets (0.02 ml) of test solution and spore suspension in equal amount were seeded in the cavity of cavity slides. These slides were kept in Petri dishes lined with moist filter paper and incubated for 24-72 hr at 24±1 °C for *U. hordei, B. sorokiniana* and at 10±1°C for *P. striiformis.* The germination of spores was recorded and the per cent spore germination inhibition was calculated.

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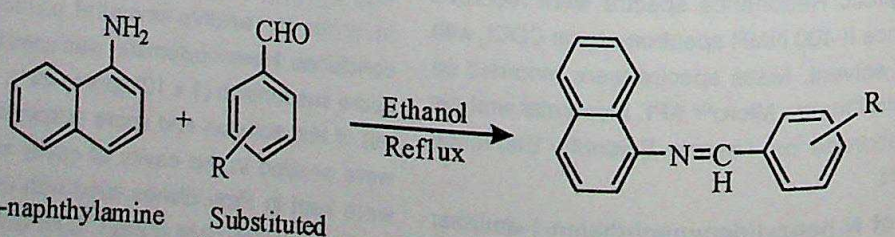
Antifungal activity for *P. grisea* and *H. oryzea* was evaluated for fungi toxicity by applying poisoned food technique. Approximately 99 ml of PDA medium was taken in the round bottom flask, 1 ml (different concentrations) of each compound was added to different flasks and the contents were mixed thoroughly. The contents of the flask were poured aseptically into the Petriplates. Test compound was, however, replaced by an equal amount of DMF (Dimethylformamide) only in the control set. After the medium solidified, one inoculum disc of the test fungi, was aseptically placed / inoculated to each, petriplate and incubated at 24±1°C. The average diameter of fungal colonies was measured on the 7th day after inoculation and percentage mycelial growth inhibition was calculated. The results were compiled in terms of ED_{50} values (effective dose to inhibit 50% spore germination).

Condensation of benzaldehyde (I), 2-nitrobenzaldehyde (II), 3-nitrobenzaldehyde (III), 4-nitrobenzaldehyde (IV), 4-methoxybenzaldehyde (V), 3,4-dimethoxybenzaldehyde (VI), 3,4,5-trimethoxybenzaldehyde (VII), 2-hydroxybenzaldehyde (VIII), 3-hydroxybenzaldehyde (IX) and 4-hydroxybenzaldehyde (X) with naphthalen-1-amine resulted in the formation of N-benzylidenenaphthalen-1-amine (Ia), N-(2-nitrobenzylidene) naphthalen-1-amine (IIa), N-(3-nitrobenzylidene) naphthalen-1-amine (IIIa) , N-(4-nitrobenzylidene) naphthalen-1-amine (IVa) , N-(4-methoxybenzylidene)naphthalen-1-amine (Va), N-(3,4-dimethoxybenzylidene) naphthalen-1-amine (VIa), N-(3,4,5-trimethoxybenzylidene) naphthalen-1-amine (VIIa), N-(2-hydroxybenzylidene) naphthalen-1-amine (VIIIa), N-(3-hydroxybenzylidene) naphthalen-1-amine (IXa) and N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa), respectively. The reaction sequence for the formation of Schiff base is given in Scheme 1.

The products were characterized on the basis of elemental analysis and spectral studies. The infrared spectra of the compounds Ia-Xa showed bands in the range of 1617-38 cm^{-1} indicating the presence of azomethinic linkage. The ^1H NMR spectra of the synthesized N-benzylidenenaphthalen-1-amines in $CDCl_3$ exhibited signals at d 8.02, 7.86, 7.86, 8.13, 8.37, 7.70, 7.13, 7.40, 7.59 and 8.13 for compounds Ia-Xa, attributed to CH=N protons, respectively. The multisignals within the range of d 6.80-9.9 were assigned to the aromatic protons of both rings. The ^{13}C NMR spectra provide further support for the structural characterization of the synthesized compounds. According to the ^{13}C NMR spectra, compounds Ia-IVa and VIIIa-Xa have 17 signals and compounds Va, VIa, VIIa have 18, 19, 20 signals, respectively. The peaks in ^{13}CNMR spectrum for compounds Ia-Xa appeared at 100-160 ppm. The carbons of methoxy group were observed at the 55-60 ppm range. These ^{13}CNMR peaks corroborated well with ^1HNMR spectra data. The mass spectra of all the synthesized compounds showed the molecular ion peak m/z at M^++1 region. The N-benzylidenenaphthalen-1-amine and its C-phenyl derivatives along with their characteristics are recorded in Table 1 and molecular ion peak with their elemental analysis are recorded in Table 2.

The synthesized compounds were screened *in vitro* for their antifungal activity against *U. hordei, P. striiformis* and *B. sorokiniana* by applying spore germination inhibition technique (Nene and Thapliyal, 1993) and by poisoned food technique (Sandhar *et al.*, 2006b) against *P. grisea, D. oryzae*. The results have been expressed in terms of ED_{50} values (Table 3).

The data presented in Table 3 showed that all the test compounds possessed promising to moderate fungi toxic potential against all the test fungi. N-(4-nitrobenzylidene)naphthalen-1-amine (IVa) was most effective against *B. sorokiniana* with ED_{50} value 220 mg/ml. Rest all the compounds possessed ED_{50} value less than 712 mg/ml against the test fungi in *B. sorokiniana* and less than 600 mg/ml in *P.grisea*. Against *D. oryzae* five test compounds inflicted promising antifungal potential *viz.* N-(2-nitrobenzylidene) naphthalen-1-amine (IIa), N-(4-nitrobenzylidene) naphthalen-1-amine (IVa), N-(3,4-dimethoxybenzylidene) naphthalen-1-amine (VIa), N-(2-



Scheme 1

R=H, 2-NO_2, 3-NO_2, 4-NO_2, 4-OCH_3, 3,4-OCH_3, 3,4,5-OCH_3, 2-OH, 3-OH, 4-OH

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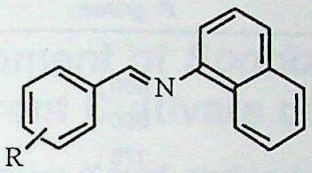
Table 1. Characteristics of N-benzylidenenaphthalen-1-amine and its C-phenyl derivatives



Compound	R	Molecular wt.	Colour	Yield (%)	m.p. (°C)
Ia	H	231	Yellow	80	67-70
IIa	2-NO_2	276	Brown	68	108-110
IIIa	3-NO_2	276	Lemon	65	97-100
IVa	4-NO_2	276	Yellow	70	146-148
Va	4-OCH_3	261	Flesh	66	83-85
VIa	3,4-OCH_3	291	Cream	63	95-97
VIIa	3,4,5-OCH_3	321	Light yellow	79	118-120
VIIIa	2-OH	247	Orange	67	105-107
IXa	3-OH	247	Yellow	72	93-95
Xa	4-OH	247	Brick red	78	142-145

Table 2. Molecular ion peak and elemental analysis of the synthesized compound

Compound	Molecular formula	Molecular ion peak	Elemental analysis		
		m+1	C% Found (Cal.)	H% Found (Cal.)	N% Found (Cal.)
Ia	$C_{17}H_{13}N$	232	88.13(88.28)	5.42(5.67)	5.92(6.06)
IIa	$C_{17}H_{12}N_2O_2$	277	72.8(73.90)	4.16(4.38)	11.02(10.14)
IIIa	$C_{17}H_{12}N_2O_2$	277	73.07(73.90)	4.33(4.38)	10.06(10.14)
IVa	$C_{17}H_{12}N_2O_2$	277	72.1(73.90)	4.27(4.38)	10.06(10.14)
Va	$C_{18}H_{15}NO$	262	80.78(82.73)	5.66(5.79)	5.13(5.36)
VIa	$C_{19}H_{17}NO_2$	292	77.9(78.33)	5.42(5.88)	4.99(4.81)
VIIa	$C_{20}H_{19}NO_3$	322	73.56(74.75)	6.02(5.96)	4.23(4.36)
VIIIa	$C_{17}H_{13}NO$	247	81.06(82.57)	5.41(5.30)	5.38(5.66)
IXa	$C_{17}H_{13}NO$	247	82.55(82.57)	5.27(5.30)	5.38(5.66)
Xa	$C_{17}H_{13}NO$	247	81.03(82.57)	5.09(5.30)	4.97(5.66)

hydroxybenzylidene) naphthalen-1-amine (VIIIa) and N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa) posessed with ED_{50} values 100, 170, 170, 128 and 198 g/ml, respectively. Against *P. grisea*, compound N-(4-nitrobenzylidene) naphthalen-1-amine (IVa) showed maximum potential with ED_{50} value 175 mg/ml. Compounds N-(4-hydroxybenzylidene) naphthalen-1-amine (Xa) and N-(4-nitrobenzylidene) naphthalen-1-amine (IVa) were the most active ones against *P. striiformis* with ED_{50} value of 115 and 162 mg/ml, respectively. Against *U. hordei*, only compound (Va) possessed moderate potential with ED_{50} value 185 mg/ml.

It is concluded from the data given in Table 3 that the substituted compounds were more potent against all the test fungi as compared to unsubstituted one. In case of nitro substituted N-benzylidenenaphthalen-1-amines, the relative order of antifungal potential is according to their position of the nitro group in the synthesized compounds. Against *P.grisea, U. hordei, P. striformis* and *B. sorokiniana*, the order of fungitoxicity was IVa > IIIa > IIa but for *H. oryzae*, was IIa > IVa > IIIa.

In case of compounds Va, VIa, VIIa, VIIIa, IXa and Xa order of reactivity also varie accordingly with different substitution. In compounds containing methoxy group as substitution, the order of reactivity for *P.grisea, U. hordei, P. striformis* and *B. sorokiniana* was Va > VIa > VIIa but for *H. oryzae* order of reactivity was VIa > Va > VIIa. Compounds having hydroxyl group at various position have the order of reactivity Xa > IXa > VIIIa for *P.grisea, U. hordei, P. striformis* and *B. sorokiniana* and VIIIa > IXa > Xa for *H. oryzae*. In terms of substituents the order of bioefficacy against *P.grisea and H.oryzae* was: $-NO_2$ > -OH > $-OCH_3$; for *U. hordei*: -

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Table 3. Antifungal activity of N-benzylidenenaphthalen-1-amine and its C-phenyl derivatives

Compound	*B. sorokiniana*	*D. oryzae*	*P. grisea*	*P. striiformis*	*U. hordei*
Ia	*	*	*	*	*
IIa	600	100	400	450	400
IIIa	525	450	350	250	375
IVa	220	170	175	162	300
Va	350	250	250	300	185
VIa	400	170	375	625	500
VIIa	513	397	418	694	667
VIIIa	712	128	437	345	564
IXa	629	505	397	286	498
Xa	461	198	215	115	401
**Tilt 25 EC	40	45	45	25	-
***Raxil	-	-	-	-	7

*more than 1000 mg/ml

** Standard fungicide for *P.grisea, D.oryzae, B.sorokiniana and P.striiformis*

*** Standard fungicide for *U.hordei*

OCH_3 > $-NO_2$ > -OH; for *P. striformis* was –OH > $-NO_2$ > $-OCH_3$ and for *B. sorokiniana* was $-NO_2$ > $-OCH_3$ > -OH.

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Indian Journal of Ecology

Comparative Development of *Spodoptera litura* (Fabricius) on Different Cultivars of Cabbage

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Cabbage, *Brassica oleracea* var. capitata (Linnaeus) is the fourth most widely grown vegetable crop of India, grown over an area of 397.41 thousand ha with a production of 8603.09 thousand MT (Anonymous, 2013). It is a biennial crop that originated from wild cliff cabbage. It is attacked by many insect pests. Among all, tobacco caterpillar, *Spodoptera litura* (Fabricius) has emerged as the most destructive insect pest on cabbage. The larva is polyphagus and feeds on mungbean, soybean and various vegetables recorded as hosts (Qin and Ye, 2007). Outbreaks of the pest occurs due to its resistance to insecticides and favourable weather conditions (Thanki *et al.*, 2003). The pest is widely distributed throughout tropical and temperate Asia, Australia and Pacific islands (Monobrulla and Shankar, 2008). Its wide spread and pest status has been attributed to its polyphagy and its ability to undergo both facultative diapause and seasonal migration (Devanand and Rani, 2008).

Keeping in view the economic importance and the emerging problem of *S. litura* on cabbage, studies were conducted on biological parameters of the insect on various cabbage cultivars. The biological parameters can help us evaluate suitability and unsuitability of different cultivars. The cultivar least preferred by the insect pest may be recommended for cultivation after field trials.

Studies on development of tobacco caterpillar, *S. litura* on different cultivars of cabbage were conducted in laboratories of the Department of Entomology, Punjab Agricultural University, Ludhiana during 2012-13. The nursery was sown on raised seed beds (150 cm x 60 cm x 20 cm) as well as in earthen pots (22.5 cm dia). The initial culture of *S. litura* was developed by collecting a large number of larvae from castor plants. The field collected larvae were reared for three generations in laboratory conditions (24 ± 1°C; 65 ± 5% R.H.) on fresh cabbage leaves. To prevent microbial infection in the culture, the cabbage leaves were washed with 0.001% potassium permanganate solution followed by rinsing with water and air drying. All the glassware used in the experiments were treated with 2% formalin and then dried in an oven at 30°C for 8 hrs. Investigation on various aspects of biology were carried out at a constant temperature of 24 ± 1°C and relative humidity of 65 ± 5% using a BOD incubator.

Larvae were reared separately on the respective hosts upto adult stage and eggs were obtained with a view to determine the incubation period and hatching percentage. The egg masses were surface sterilized with 0.02% sodium hypochlorite solution, dried and allowed to hatch. The petri-plates (7.5 cm x 1.25 cm) having leaves of different cultivars with eggs were kept in an incubator. The egg duration and number of larvae hatched were recorded. To determine, duration of different larval instars, total larval duration and larval survival percentage, the individual larvae in four replications with fifty larvae in each were transferred in a plastic vial (2.5 cm x 7.5 cm) and provided with fresh food. The food was changed daily in the morning and observations for the exuviae as well as head capsule were taken to confirm moulting. The number of larvae which successfully pupated were counted to work out the larval survival. The initiation of pre-pupal stage was confirmed by the presence of a sluggish and dark coloured larva that stopped feeding. The pre-pupa was transferred to the jars containing sterilized soil to facilitate pupation. The pupae formed were transferred to another set of vials containing sponge covered with blotting paper. Out of the total pupae, the pupae from which the moths emerged were counted and per cent pupal survival was worked out. The observation was taken daily to record the pupal period, pupal weight and adult emergence. The male and female adults emerged from the respective hosts on the same day were paired in mating chambers and provided with 10 per cent honey solution on cotton swab as food. The adult longevity was taken as the time interval between the emergence of adults and its death. To know the fecundity, the eggs oviposited on the leaves were counted daily under the microscope. Fresh leaves were introduced for subsequent oviposition. The total life cycle was calculated from the time of egg laying till the emergence of moths.

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Significantly lower incubation period was recorded on Pusa Mukta (4.27 days) followed by Golden Acre and KGMR-1 being at par with each other as compared to other cultivars (Table 1). Maximum incubation period was observed on Pride of India (4.87 days) followed by Pusa Drum Head being on par with each other. More or less similar result has been reported by Soni *et al.* (2001) who observed the mean incubation period of 5.60 days on cabbage. The maximum hatchability (86.66 %) was on Pusa Mukta being on par with Golden Acre. Minimum hatchability was on Pride of India followed by Pusa Drum Head and KGMR-1.

The larvae moulted four times and passed through five instars. The mean duration of first instar larvae varied significantly from 2.75 to 3.90 days with a minimum duration on Pusa Mukta which was statistically on par with Golden Acre. These were followed by KGMR-1, Pride of India and Pusa Drum Head (Table 1). The minimum mean duration of second instar larvae was on Pusa Mukta (3.66 days) with non significant variation from Golden Acre, but differed significantly from KGMR-1, Pusa Drum Head and Pride of India. The duration of third instar larvae was minimum on Pusa Mukta (3.37 days). It was statistically on par with Golden Acre but differed significantly from KGMR-1, Pusa Drum Head and Pride of India which were on par with each other. The durations of fourth and fifth instar larvae showed a similar trend to that of third instar. The total larval duration was found to be minimum on Pusa Mukta (15.55 days) which was statistically on par with Golden Acre and it differed significantly from KGMR-1 and Pusa Drum Head. Maximum larval duration was observed on Pride of India (20.09 days) and it varied significantly from other cultivars. The findings of the present study are similar to the results reported by Shahout *et al.* (2011) on cabbage.

The minimum survival of larvae was on Pride of India (71.00%) followed by Pusa Drum Head and was lower significantly from KGMR-1 and Golden Acre. Maximum larval survival was however recorded on Pusa Mukta (89.00 %). Xue *et al.* (2010) found larval survival of 75.04 per cent on Chinese cabbage whereas Chand and Tripathi (2008) had reported 91.00 per cent larval survival on cabbage. Minimum pre-pupal period was observed on Pusa Mukta (2.26 days) followed by Golden Acre, KGMR-1, Pusa Drum Head and Pride of India (Table 1). Maximum pupal period was recorded on Pride of India (9.08 days) which varied significantly from KGMR-1 and Pusa Drum Head. The minimum pupal period was observed on Pusa Mukta (6.38 days) which was on par with Golden Acre.

Table 1. Effect of cabbage cultivars on incubation period and hatchability of eggs; larval duration and survival; pre-pupal, pupal period, pupal weight and survival; adult longevity, pre-oviposition, oviposition, post oviposition period and fecundity of *S.litura* (Mean ± SE)

Cultivar Stage	Pride of India	Pusa Drum Head	KGMR-1	Golden Acre	Pusa Mukta	CD (p=0.05)
Incubation period (days)	4.87±0.10	4.75±0.11	4.53±0.11	4.38±0.07	4.27±0.09	0.29
Hatchability of eggs (%)	81.76±1.06	82.74±1.03	83.80±0.85	85.18±0.90	86.66±0.82	2.82
Laval stage						
I instar	3.85±0.15	3.90±0.05	3.74±0.06	2.85±0.05	2.75±0.04	0.54
II instar	4.68±0.12	4.60±0.011	4.49±0.096	3.67±0.07	3.66±0.09	0.68
III instar	4.15±0.04	4.06±0.05	3.96±0.07	3.39±0.09	3.37±0.06	0.20
IV instar	4.01±0.06	3.87±0.11	3.84±0.06	3.06±0.05	3.03±0.07	0.57
V instar	3.40±0.04	3.37±0.04	3.35±0.03	2.78±0.05	2.74±0.09	0.17
Total larval duration (days)	20.09±0.14	19.80±0.21	19.38±0.16	15.75±0.26	15.55±0.12	0.56
Pre pupal period (days)	2.89±0.10	2.79±0.05	2.78±0.01	2.32±0.02	2.26±0.02	0.16
Pupal period (days)	9.08±0.05	8.94±0.03	8.89±0.03	6.43±0.08	6.38±0.03	0.15
Pupal survival (%)	80.00±2.42	80.00±2.08	84.00±2.04	88.00±2.16	92.00±1.83	6.37
Pupal weight (g)						
Male	0.349±0.003	0.350±0.00202	0.354±0.002	0.359±0.003	0.362±0.003	0.008
Adult longevity (days)						
Male	4.90±0.07	4.87±0.03	4.82±0.13	4.75±0.09	4.70±0.07	NS
Female	6.31±0.05	6.27±0.10	6.27±0.10	6.14±0.03	6.04±0.06	NS
Pre-oviposition period (days)	2.02±0.06	2.12±0.03	1.97±0.05	2.10±0.04	2.12±0.03	NS
Oviposition period (days)	2.52±0.05	2.45±0.09	2.55±0.10	2.47±0.09	2.42±0.05	NS
Post oviposition period (days)	1.77±0.08	1.70±0.04	1.75±0.10	1.57±0.07	1.50±0.04	NS
Fecundity	137.82±2.94	140.55±2.59	142.35±1.38	144.47±1.69	144.80±2.31	1.11
Total life cycle (days)	36.93±0.25	36.28±0.35	35.58±0.14	28.88±0.43	28.46±0.54	

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The female pupae weighed heaviest on Pusa Mukta, which was on par with Golden Acre but was significantly higher than that on KGMR-1, Pusa Drum Head and Pride of India. Similar trend was observed in case of male pupae also.

The maximum pupal survival of 92.00 per cent was observed on Pusa Mukta followed by Golden Acre, which was significantly higher than all other cultivars (Table 1). Xue *et al.* (2010) also reported a high pupal survival of 91.4 per cent to 95.9 per cent on different host plants, which was attributed to climatic and host variations.

There were no significant differences among five cultivars in pre-oviposition, oviposition and post-oviposition periods (Table 1). The pre-oviposition period ranged from 1.97 days on KGMR-1 to 2.12 days on Pusa Drum Head and Pusa Mukta. Maximum oviposition period was recorded on KGMR-1 followed by Pride of India, Golden Acre, Pusa Drum Head and Pusa Mukta whereas post-oviposition period was found to be the minimum on Pusa Mukta and maximum on Pride of India.

Longevity of adult moths did not differ significantly on different cultivars of cabbage. However, in general, females lived longer than males. Adult longevity ranged from 4.70 days to 4.90 days in males and 6.04 days to 6.31 days in case of females on different cultivars (Table 1). In contrast to present findings, Xue *et al.* (2010) reported males to live longer (7.4 days) than females (6.6 days) on Chinese cabbage. There were non significant differences in the fecundity of *S. litura* on different cultivars. Maximum fecundity was observed in case of Pusa Mukta (144.80 eggs/ female) followed by Golden Acre, KGMR-1, Pusa Drum Head and Pride of India. In contrast Soni *et al.* (2001) reported a higher fecundity of 557.06 and 397.63 on cabbage and cauliflower, respectively. Total life cycle was found to be minimum on Pusa Mukta (28.46 days) followed by Golden Acre being on par with each other (Table 1). Maximum life cycle duration was on Pride of India differing significantly from Pusa Drum Head and KGMR-1 (35.58 days)

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From the present study, it may be concluded that out of five cultivars of cabbage, Pride of India recorded lowest fecundity, hatchability of eggs with maximum incubation, larval, pre-pupal and pupal periods while the cultivar Pusa Mukta recorded maximum fecundity, hatchability of eggs with minimum period of various developmental stages. Thus, the cultivar Pride of India, due to lower suitability, can help in reducing the population of *S. litura* on cabbage. The reasons for lower suitability need to be elucidated further investigations.

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Efficacy of Plant Extracts Against Fusarium Wilt of Tomato

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Fusarium species caused a huge range of diseases on an extraordinary range of host plants. The fungus can be recovered from any part of the plant from the deepest root to the highest flower (Booth, 1997 and Summeral *et al.*, 2003). Wilt of tomato (*Lycopersicon esculentum*) caused by *Fusarium oxysporum* f.sp. *lycopersici* is a disease that cause serious economic losses (Agrios, 2005). The fungus causes vascular wilts by infecting plants through the roots and growing internally through the cortex to the stele (Bowers and Lock, 2000). Control of wilt diseases depends mainly on fungicides (Minton, 1986). Several fungicides have been used for control of different plant pathogens including fusaria (Liggit et al., 1997) and the number of effective fungicides with negligible effect on the environment is rare. Fungicides are expensive, can cause environmental pollution and may cause the selection of pathogen resistance (Zhonghua and Michailides, 2005). Due to the aforementioned considerations, there is a need to develop new management systems to reduce the dependence on synthetic agrochemicals. Recent trend favour the use of alternative substances derived from natural plant extracts to control diseases (Xuan *et al.*, 2003 and Islam *et al.*, 2004). The dried leaves of *Ocimum sanctum* L. have been mixed with stored grains to repel insects (Biswas and Biswas, 2005). Alternative methods of controlling the disease have been studied with emphasis on novel compounds derived from plant sources (Albouvettle, 1999). Plants are good alternatives to chemical pesticides, as they are readily biodegradable in nature.

The aim of the present study was to compare the effect of extracts of *Ocimum sanctum, Aegle marmelos, Citrus limon, Putranjiva roxburghii* and fungicide Bavistin (Carbendazim 50% WP) on *F. oxysporum* f.sp. *lycopersici* mycelial growth and spore germination *in vitro*.

Preparation of extracts: Extracts from leaves of four plants namely *Citrus limon, Putranjeeva roxburghii, Ocimum sanctum* and *Aegle marmelos* were collected from field of Punjab Agricultural University, Ludhiana and tested for their efficacy in reducing the mycelial growth and spore germination of *Fusarium oxysporum* f.sp. *lycopersici in vitro* using the poisoned food technique (Nene and Thapliyal, 1993). Plant leaves extract was prepared according to Sallam (2011). Ten grams of fresh leaf material of each plant species were collected, washed with water and crushed in a grinder by adding sterile distilled water at the rate of 10 ml gm^{-1} of plant tissue and the homogenates were centrifuged at 10,000 rpm for 15 minutes and the supernatant solutions were collected. The plant extract was diluted further to have 10 and 20% concentration (v/v). These fractions were sterilized using 0.22 µm milipore filter assembly and used for assay of antifungal activity as described below.

The filtrate of each plant extract was mixed with autoclaved PDA medium at 10 and 20% concentration. Plant extract supplemented medium was poured in sterilized Petri plates and allowed to solidify. These Petri plates were inoculated at the centre with a 5 mm agar disc from the 7 days old fungal culture of *F. oxysporum* f.sp. *lycopersici*. In control, a Petri plate containing PDA media with requisite amount of sterilized water instead of a plant extract was also inoculated with a plant pathogen. Bavistin (Carbendazim 50% WP) was used as positive control of fungi and sterilized water was used to prepare stock solution. The inoculated Petri plates were then incubated at 25±2°C for 7 days. The diameter of the fungal colony was measured using a meter rule along two diagonal lines drawn on the reverse side of each Patri plate 24 hrs after inoculation. Each treatment was replicated three times with three plates per replication. Percentage inhibition of mycelia growth was calculated and statistical analysis of the data was done using Completely Randomized Block Design (CRD).

In the present study, 20% concentration of aqueous extracts of plant leaves of *Citrus limon, Putranjeeva roxburghii, Ocimum sanctum* and *Aegle marmelos* and 0.2% fungicide Bavistin were evaluated for their effect on the spore germination of test fungus. Spore suspension of each isolates of fungus containing 30-40 spores per microscopic field was prepared from 10 days old culture. One drop of about 0.1 ml of spore suspension was placed in a cavity glass slide containing a drop (about 0.1 ml) of 20% concentrations of plant extract. These slides were kept in moist chamber

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prepared putting two folds of filter paper in both sides of Petri plates. These plates were incubated at 24±2°C and reading in terms of germinated and spores were taken at 2 hours intervals up to 24 hours.

Effect of Plant Extracts on Radial Growth and Spore Germination of *Fusarium oxysporum* f.sp. *lycopersici*

Four plant species were selected and evaluated for their antifungal activity against *F. oxysporum* f.sp. *lycopersici*. All the leaf extracts of tested plants at 10% and 20% concentration were effective in inhibiting the radial growth of test pathogen compared to control. The leaf extract of *O. sanctum* and *A. marmelos* at 20% concentration caused highest reduction of mycelial growth of *F. oxysporum* f.sp. *lycopersici* i.e. 70.9 and 60%, respectively followed by *C. limon* and *P. roxburghii* at10 and 20% concentration. Overall the Bavistin at 0.2% caused the highest reduction of the pathogen by 80.5% (Figure 1).

Present investigation showed that *O. sanctum* extract have potential to inhibit mycelia growth and spore germination of *F. oxysporum* f.sp. *lycopersici*. Amadioha (2000) proved that *O. gratissimum* leaf extracts has ability to inhibit spore germination and mycelial growth of *Rhizopus oryzae*. Mycelial growths of various *Fusarium* spp. were inhibited by plant extracts *of Adhatoda vasica, Azadirachta indica, Cinnamomum camphora* and *Ocimum sanctum* (Prasad and Ojha, 1986). The presence of antifungal substances in the different extracts, which caused the inhibition of radial growth and spore germination *in vitro* and reduction in rot development by the pathogen *in vivo*. Vijayan (1989) reported that the bulb extract of *A. sativum*, leaf extract of *Aegle marmelos* and flower extract of *Catharanthus roseus* inhibited the spore germination and mycelial growth of *Alternaria solani*. Daya and Ram (1997) reported that leaf extracts of *O. sanctum* was found most effective against *Alternaria brassicae* as compared to other tested extracts.

Table 1. Effect of plant extracts on the spore germination of *F. oxysporum* f.sp. *lycopersici*

S. No.	Plant extracts	Spore germination (%)	Spore germination inhibition (%)
1.	Citrus limon	75.57 (60.43)	22.96
2.	Aegle marmelos	61.67 (51.73)	37.14
3.	Ocimum sanctum	23.00 (28.67)	76.55
4.	Putranjeeva roxburghii	76.67 (61.69)	21.85
5.	Bavistin (Positive control)	4.47 (11.87)	95.44
6.	Control	98.10 (82.23)	0.0
	CD (0.05)	4.31	-

Leaf extracts of *O. sanctum* inhibited the spore germination of *F. oxysporum* f. sp. *lycopersici* 76.67 per cent maximally and *P. roxburghii* leaf extracts inhibited the least. Overall the Bavistin showed the highest inhibitory effect on spore germination of test pathogen (Table 1).

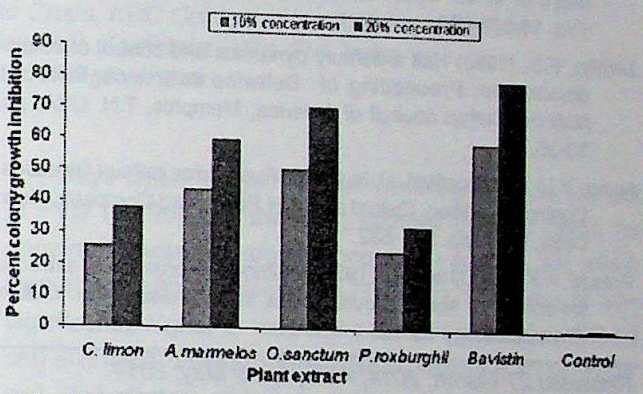

Fig. 1. *Effect of plant extracts on the mycelia growth of* F. oxysporum *f.sp.* lycopersici *in vitro.*

The present study concludes that aqueous extracts of *Ocimum sanctum*, *Aegle marmelos* and *Citrus limon* contain antifungal constituents for the control of *F. oxysporum* f.sp. *lycopersici* with varying degree of efficacy. *Ocimum sanctum* was found to be the highly effective plant extracts amongst tested crude plant extracts. Further green house and field experiments are suggested to investigate the *in vivo* effects of these extracts as compared to some commercial chemical fungicides for the management of *Fusarium* wilt of tomato.

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Indian Journal of Ecology

Effect of Propagation Media on Growth of Turmeric Sprouts

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India is the world's largest producer and exporter of turmeric and it produces nearly 50 per cent of global turmeric. It is grown in an area of 1.92 lakh hectares with an average production of 8.93 lakh MT (Anon., 2012). The cost of planting material amounts to 50 % of crop production in turmeric. Studies on the use of different rhizome size, propagation media and growth regulators are scanty. Hence, there is a need to study the effect of propagation media on the turmeric sprouts, rhizome size and growth regulators on growth, yield and quality under field conditions. The effect of growing media on sprouting and growth of turmeric is important to know the best suited potting media for growth of turmeric.

The study was carried out in the laboratory of Plantation, Spices, Medicinal and Aromatic Crops Department of Kittur Rani Chennamma College of Horticulture, Arabhavi during May of 2012-2013. There were twelve treatments (Table 1) in complete randomized design with three replications. The composition of the different media were incorporated in trays with 20 holes and rhizomes of 25 g size each, which were used for planting in trays. Out of twenty plants, observation on growth parameters were recorded in five randomly selected uniform healthy plants.

Days taken for germination were significantly highest in FYM (15.00) and the least number of days taken for germination was recorded in coco peat + sand (6.33), which was at par with vermicompost (Table 1). Plant height was significantly higher in red soil + sand + coco peat (41.56 cm) and least where rhizomes were planted in FYM (12.67 cm). Pseudostem girth was significantly highest (8.48 mm) in Red soil + sand + coco peat, which was at par with Red soil + sand + vermicompost and the least pseudostem girth (2.53 mm) was recorded in FYM. Highest number of leaves and sprouts were recorded in red soil + sand + coco peat, which differed significantly from all other treatments. The minimum number of leaves were recorded in FYM and the least sprouts in coco peat. Similarly, the maximum (120.64 cm^2) was in the red soil:sand:coco peat in equal proportion, which significantly differed from all other treatments and the least leaf area was recorded in FYM (29.37 cm^2). Early germination was observed in coc-peat + sand and vermicompost might be due to improvement in physico-chemical property of growing media i.e., coco peat + sand. These results confirm the earlier findings in nutmeg by Abirami *et al.* (2010 a) and Ali *et al.* (2012), wherein improved

Table 1. Effect of type of media on days taken for germination, plant height, pseudostem girth, leaves per plant, number of sprouts and leaf area in turmeric var. Suroma

Treatments	Days taken for germination	Plant height (cm)	Pseudo stem girth (mm)	No. of leaves plant^{-1}	No. of sprouts	Leaf area (cm^2)
Coco peat	10.33	21.67	4.55	0.87	0.93	54.19
Coco peat + Sand (1:1)	6.33	21.61	6.52	0.97	1.00	58.88
FYM	15.00	12.67	2.53	1.00	1.00	29.37
FYM + Sand (1:1)	7.66	23.90	5.30	0.80	1.00	33.31
Vermicompost	6.66	27.61	6.78	1.00	1.07	78.95
Vermicompost + Sand	7.33	30.60	6.25	1.00	1.00	67.97
Red soil	10.00	29.67	5.43	1.03	1.07	64.72
Red soil + Sand (1:1)	9.33	35.85	6.34	1.20	1.07	77.34
Red soil + Sand + FYM (1:1:1)	8.34	20.51	5.47	1.27	1.00	62.91
Red soil + Sand + Vermicompost (1:1:1)	9.00	25.78	7.67	1.50	1.00	73.76
Red soil + Sand + Coco peat (1:1:1)	8.66	41.56	8.48	3.13	2.03	120.64
Sand	7.66	26.79	6.56	1.20	1.10	66.20
CD (1%)	1.61	3.50	0.73	0.31	0.15	10.57

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physico-chemical properties of the soil resulted in early germination. This may be attributed to the moisture retention property of coco peat and the mixture of sand and red soil, which improved the texture of the growing media for better root growth, resulting in production of more number of roots for better absorption of nutrients from the growing media leading to synthesis of more photosynthates due to increased leaf area. Similar results were reported by Abirami *et al.* (2010 b) in nutmeg, Thankamani *et al.* (1996) in clove and Mutiarawati (2001) in asparagus.

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Indian Journal of Ecology

Heterosis Studies in Near Homozygous Lines of Brinjal (*Solanum melongena* L.) for Yield and Yield Attributing Traits

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Brinjal (*Solanum melongena* L.), an important member of family *Solanaceae* is an important crop in the tropical regions of world and being grown extensively. A number of cultivars are grown in India based on consumer preference for fruit color, size, shape and taste. The phenomenon of heterosis in plants is well known today and breeders exploit it for higher yield in crop plants and is an efficient approach for improvement of vegetable crops brinjal continues to be a choice of breeders for exploitation of heterosis due to hardy nature of crop, comparatively large size of flowers and large number of seeds in a single act of pollination. Hybrids offer opportunities for improvement in earliness, uniformity, productivity, quality, wider adaptability and rapid deployment of dominant genes for resistance to disease and pests. Information on the magnitude of heterosis in different cross combination is a basic requisite to assess for identifying crosses that exhibit high amount of exploitable heterosis. With these points in view, the present investigation was undertaken to study the heterosis in hybrids for plant growth, earliness, yield and its components.

Fifteen lines (KB-12-01, KB-12-02, KB-12-03, KB-12-04, KB-12-05, KB-12-06, KB-12-07, KB-12-08, KB-12-09, KB-12-10, KB-12-11, KB-12-12, KB-12-13, KB-12-14 and KB-12-15) were crossed to three testers (KRCB-1, KRCB-2 and KRCB-3) during March, 2012. The F1 seedlings along with their parents were planted in randomized block design with two replications at Department of Vegetable Science, Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district (Karnataka) during September 2012. Each entry was represented by two rows of 16 plants with spacing of 75 X 60 cm. Five competitive plants from each entry were selected randomly and data recorded for all the growth, earliness, yield and quality parameters. The heterosis over better parent, the best parent and the commercial check (Super 10) in percentage was calculated for these characters.

The sum of squares due to genotypes was highly significant for diversity among the genotypes (Table 1). Mean sum of squares due to genotypes, parents as well as crosses were also highly significant for all the traits and indicating presence of variability among parents and genotypes. Hence, results obtained were in desirable direction. The standard heterosis (CC-Commercial check) for plant height ranged from 8.80 to 13.47. Similarly, 13.92 to -7.59 for days to first flowering, 20.72 to -7.21 for days to fifty per cent flowering, -66.67 to 25.00 for per cent fruit set, -32.25 to

Table 1. Analysis of variance (mean sum of squares) of line x tester analysis for ten parameters in brinjal

Sr. No	Character	Replication	Genotypes	Parents	Parents vs Crosses	Crosses	Lines	Testers	Line x Tester	Error
		1	62	17	1	44	14	2	28	62
1.	Plant height q	0.57	36.49**	44.70 **	57.15 **	32.84**	44.66NS	32.49 NS	26.99 **	1.36
2.	Days to first flowering	0.03	18.05**	19.20 **	221.25 **	13.29 **	14.20 NS	8.84 NS	13.16 **	1.59
3.	Days to 50 per cent flowering	0.06	50.23**	30.89**	934.29**	38.05**	59.01NS	16.58 NS	29.07 **	1.61
4.	Per cent fruit set (%)	0.08	630.10 **	159.64**	2956.26**	762.72**	1632.85**	463.33NS	349.04 **	1.61
5.	Average fruit weight (g)	3.49	536.98**	245.38**	3499.93**	594.48 **	510.92 NS	328.01 NS	655.29**	2.22
6.	Fruit length (cm)	1.58	2.03**	2.30 **	0.81 NS	1.99 **	2.25NS	1.79 NS	1.87 **	0.36
7.	Fruit diameter (cm)	0.25	0.67**	0.37 **	1.77 **	0.77 **	1.26 *	0.01 NS	0.58 **	0.08
8.	Number of fruits per plant	1.78	17.63**	9.80 **	28.34 **	19.37 **	23.13 NS	10.54 NS	18.12 **	0.81
9.	Yield per plant (kg)	0.011	0.19**	1.59**	0.83**	0.21**	0.12NS	0.18 NS	0.26**	0.065
10.	Yield per hectare (t ha^{-1})	7.11	62.29**	776.54**	103.23**	68.24 **	109.65*	87.67 NS	46.15**	2.77

*and** Indicate significance of values at p=0.05 and p=0.01, respectively. NS: Not significant, DAT: Days after transplanting

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Table 2. Magnitude of heterosis, *per se* performances and best hybrids for ten characters

Character	Magnitude of heterosis			Range of *perse* performance	No. of hybrids having significant heterosis (over CC)		Best hybrids over commercial check
	BP	BTP	CC		+ ve	-ve	
Plant height	-12.71 to 17.57	-15.48 to 5.16	-8.80 to 13.47	80.90 to 100.64	24	5	KB-12-08 × KRCB-3, KB-12-07 × KRCB-2 and KB-12-01 × KRCB-1
Days to first flowering	13.92 to -22.22	13.92 to -7.59	13.92 to -7.59	36.50 to 45.06	20	20	KB-12-05 × KRCB-1, KB-12-06 × KRCB-3 and KB-12-12 × KRCB-1
Days to fifty per cent	13.91 to -21.21	21.82 to -6.36	20.72 to -7.21	51.50 to 67.00	14	10	KB-12-09 × KRCB-1, KB-12-05 × KRCB-1 flowering and KB-12-05 × KRCB-2
per cent fruit set	-60.00 to 133.33	-60.00 to 50.00	-66.67 to 25.00	20.00 to 75.00	15	28	KB-12-11 × KRCB-2, KB-12-09 × KRCB-3 and KB-12-06 × KRCB-2
Fruit length	-37.00 to 35.32	-44.92 to 0.94	-23.85 to 39.55	7.24 to 11.45	32	7	KB-12-14 × KRCB-2, KB-12-03 × KRCB-2 and KB-12-01 × KRCB-1
Fruit diameter	-23.22 to 22.70	-29.74 to 22.84	-12.74 to 52.56	4.90 to 8.55	24	18	KB-12-09 × KRCB-3, KB-12-05 × KRCB-1 and KB-12-12 × KRCB-1
Average fruit weight	-34.73 to 75.89	-37.13 to 38.92	-32.25 to 49.61	52.61 to 116.00	21	19	KB-12-06 × KRCB-3, KB-12-07 × KRCB-1 and KB-12-05 × KRCB-2
Number of fruits plant^{-1}	-42.55 to 13.95	-42.55 to 4.25	-35.70 to 16.70	13.50 to 24.50	13	32	KB-12-03 × KRCB-1, KB-12-07 × KRCB-3 and KB-12-10 × KRCB-1
Yield plant^{-1}	-40.66 to 74.72	-51.46 to 23.31	-47.81 to 31.77	.85 to 1.77	15	25	KB-12-06× KRCB-2, KB-12-11 × KRCB-2 and KB-12-01 × KRCB-3
Yield hectare^{-1}	-40.70 to 41.38	-51.43 to 1.87	-47.76 to 9.57	18.85 to 39.60	10	24	KB-12-11 × KRCB-2, KB-12-06 × KRCB-2 and KB-12-01 × KRCB-3

BP-Better parent heterosis, BTP- Best parent heterosis and CC- Commercial check.

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49.61 for average fruit weight, -23.85 to 39.55 for fruit length, -12.74 to 52.56 for fruit diameter, -35.70 to 16.70 for number of fruits per plant, -47.81 to 31.77 for yield per plant and -47.76 to 9.57 for yield per hectare. These results are little higher compared to earlier studies reported by Chowdhary *et al.* (2011) for plant height and days to fifty per cent flowering, Nalini *et al.* (2011) for days to first flowering, Bavage (2002) for per cent fruit set, Bulgundi (2000) for average fruit weight, Prakash *et al.* (2008) for fruit length and diameter, Abhinav and Nandan (2010) for number of fruits per plant, whereas, Sharma (2010) reported little higher heterosis for yield per hectare. Kamani and Monpara (2009) reported the heterosis for yield per plant, which was lower than present study. The best hybrids for yield per hectare were KB-12-11 X KRCB-2, KB-12-01 X KRCB-3, KB-12-12 X KRCB-3 and KB-12-03 X KRCB-3. These hybrids also exhibited specific combining ability for yield per hectare hence the heterosis was associated with sca. This indicates the presence of non-additive gene action. These heterotic hybrids were obtained from H x L, H x H, L x L and H x A. However, higher proportion of heterotic hybrids were obtained from H x L type of combination. This information will be further useful in the precise selection of parents to get the highly heterotic hybrids.

Ten hybrids showed the standard heterosis for yield per hectare and also yield attributing traits in positive direction. Hence results were associated with non- additive gene action. This indicates that parents have the specific combining ability for these traits.

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Indian Journal of Ecology

Biology of Banana Pseudostem Weevil, *Odoiporus longicollis* Olivier

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Banana is an important plantation crop but its production is constrained by a number of insect pests. Amongst pseudostem weevil, *Odoiporus longicollis* Oliver (Coleoptera: Curculionidae) is a major one. It is estimated that banana pseudostem borer causes 10-90 per cent yield loss depending on the growth stage of the crop and management efficiency. Attempts have been made by different workers to study the biology of this pest. As this pest has been reported only recently from Karnataka. Present study was undertaken to generate detail information on biology of insect.

Studies on the biology of the banana pseudostem borer; *O. longicollis* were conducted in the laboratory for one season during October to January, 2013 at Department of Horticulture Entomology, College of Horticulture, Mudigere, Chikmagalur, Karnataka, India. The population was raised from a field strain of *O. longicollis*. Freshly emerged individual pairs of weevils were released in plastic boxes (7 x 14 cm) with strip of pseudostem (4-8 cm) and replicated 10 times. The strips of pseudostem were replaced on every third day. Egg containing pseudostems were kept in separate plastic boxes having moist filter paper to record incubation period on hatching, the grubs were transferred to fresh pseudostems having artificial holes. For recording the number and duration of instars, the grubs were taken out of pseudostem and tunnels were examined for moulting skin. The same procedure was adopted for recording pre-pupal and pupal duration. The same set explained above was used for determining pre-oviposition, oviposition and post-oviposition periods, fecundity and longevity of the adults.

The pre-oviposition period lasted for 18 to 27 days with an average of 23.90 ± 2.85 days. Oviposition occurred both during day and night hours. The oviposition period varied from 20 to 25 days with an average of 23.30 ± 1.70 days. The post oviposition period varied from 15 to 18 days with an average of 16.90 ± 1.20 days. These observations are in agreement with the findings of Padmanaban and Sathiamoorthy (2001).

Incubation period : The egg was laid singly inside the air chamber; freshly laid egg was translucent and yellowish in colour. The incubation period varied from 3.50-6.00 days (Av. 4.80 ± 0.90) during October to January. Mean fecundity was 16.90 ± 2.42.

Larva: The grub passed through five instars to complete the larval period. Before moulting, the grub stopped feeding and boring. Freshly moulted grubs were white in colour except mandibles, which were light brown coloured. Freshly emerged larva was yellowish white, apodus, soft, wrinkled, bulged in the middle and pointed towards both ends. Later on, as the cuticle colour changed to creamy white and the head capsule became light reddish brown. The first instar lasted for 3.00 to 4.00 (Av. 3.60 ± 0.46) days. Morphometrically second instar was similar to that of first instar except the size, and segments, which were clearly visible. The second instar occupied 4.00 to 5.00 (Av. 4.60 ± 0.52) days.

Head was yellowish brown with anterior margin of cranium reddish brown. The body appeared whitish in colour. Other characters were similar to first and second instars. The abdomen gradually broadened posteriorly. This instar occupied 5.50 to 6.50 (Av. 5.95 ± 0.44) days. Similar to third instar grub in all respect except for the increase in size and rounded posteriorly. The instar occupied 7.50 to 8.50 (Av. 8.10 ± 0.39) days.

Fifth instar was yellowish white, stout, fleshly and head free, reddish brown in colour and rounded abdominal tip. Mandibles stout, more or less triangular with bluntly pointed three apical denticles. Small circular shiny areas and minute setae were sparsely distributed all over the body. Dorsal segments were wrinkled and indistinct and ventrally segmentation appeared clearer. The sloping of the truncate abdominal tip starts from 8th abdominal segment. There were nine pairs of spiracles situated laterally. This instar occupied 13.50 to 16.00 (Av. 15.15 ± 0.88) days. The total larval period varied from 33.50 to 40.00 (Av. 37.40 ± 2.69) days during October to January.

Pre-pupa and pupa: Matured larva constructed the cocoon and the size of the pre-pupa was about $^{2}/_{3}$ rd of

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larva. The pre-pupa was characterized by change in colour to pale yellow. The pre-pupal period lasted for 3.50 to 6 (Av. 4.52 ± 0.82) days during October to January. These observations are in agreement with the findings of Kung (1964). The pupa was exarate type; yellowish in colour with setae on the head and base of the rostrum and a tuft of hairs on the anal region. The pupal period lasted for 19.50 to 23 (Av. 21.13 ± 1.31) days during October to January. Similar observations were reported by Dutt and Maiti (1972).

Total life cycle: The total life cycle of *O. longicollis* from egg to adult emergence varied from 60 to 75 (Av. 67.85 ± 5.72) days during October to January. Similar observations were reported by Padmanaban and Sathiamoorthy (2001). The adult individuals reared in the laboratory survived for 71 to 98 days with an average of 84.10 ± 10.02 days during October to January. These findings are more or less in agreement with the findings of Visalakshi *et al.* (1989).

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Indian Journal of Ecology

Effect of Different Cooking Methods on Total Phenolic Content of Selected Vegetables

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Phenolic compounds, commonly found in plants, been associated with flavour and colour characteristics of fruits/ vegetables have multiple biological effects, including antioxidant activity and play a preventive role in the development of cancer/heart diseases by slowing the progression of atherosclerosis by acting as anti-oxidants towards low-density lipo-proteins (Kahkonen *et al.,* 1999). The anti-oxidant activity of phenolics is mainly because of their redox properties which allow them to act as reducing agents, hydrogen donors, singlet oxygen quenchers and metal chelators (Rice-Evans *et al.,* 1997). Vegetables are one of the most valued components for their colour, flavour, therapeutic and nutritional value in the Indian culinary as majority of Indian population is vegetarian. Many Brassicaeae crops (e.g. broccoli, brussels sprouts, cabbage and cauliflower) commonly known as crucifers have been associated with inhibition of chemically induced carcinogenesis. Broccoli is high in polyphenols. Capsicum are rich sources and green leafy vegetables contain an immense variety of bioactive non-nutritive health enhancing factors such as antioxidants, phytochemicals, essential fatty acids and dietary fiber.

Processing, particularly cooking is a crucial factor that has an impact on total antioxidant activity of any food material, especially for vegetables, since most of them are commonly eaten in cooked form. The present study is conducted to evaluate the effect of different cooking methods on the phenolic content of the selected vegetables.

Five commonly consumed vegetables viz. spinach, fenugreek leaves, broccoli, cabbage and capsicum were procured from the local market during the peak season (January 2012) and were randomly sampled from the shelf. Vegetables were washed with tap water after removing inedible parts manually with knife and then were cut into almost equal pieces and mixed well. Four hundred grams of each vegetable were taken and divided into four portions of hundred grams each. One portion was retained raw; others were cooked by three most common methods to cook vegetables viz. cover lid cooking (CLC), microwaving (MW) and stir frying (SF). Cover lid cooking: One hundred gram of each vegetable was cooked with added water at 5, 10 and 15 min interval in a pan covered with a lid. Microwaving: One hundred gram of each vegetable was cooked in a microwave safe glass container and cooked in domestic microwave (Samsung CE2933) with added water at 5, 10 and 15 min interval. The content of added water during CLC and MW was determined with a preliminary experiment for each vegetable and cooked for the three time periods. Stir frying: One hundred gram of each vegetable was stir fried in a pan with ten grams of refined soyabean oil per vegetable sample. The vegetables were stir fried for 5, 10 and 15 min interval while stirring the sample frequently and without putting the lid on. All the samples were then cooled rapidly under the fan and sealed in air tight pouches for further analysis. Fresh: One hundred gram of fresh uncooked and almost equally and evenly cut vegetables were taken and used for analysis.

The selected vegetables cooked by above mentioned methods for three time periods i.e. 5, 10 and 15 min were evaluated for the sensory characteristics namely colour, appearance, texture, flavor, taste to assess the overall acceptability by the panel of 10 judges using a nine point hedonic scale (Ranganna, 1986). The method of Singleton *et al.* (1999) was followed to estimate total phenols by using Folin–Ciocalteau reagent. The methanolic extracts for the samples of raw and cooked vegetables were prepared by keeping overnight in methanol.

The results of the sensory evaluation revealed that maximum overall acceptability of vegetables i.e. spinach, fenugreek, broccoli, cabbage and capsicum was at 15, 10, 5, 10 and 10 min. during cover lid cooking and microwave cooking, while it was at 10, 15, 5, 10 and 10 min during stir frying (Table 1). Total phenolic content (TPC) of analyzed vegetables ranged between 117.2 to 396.6 mg/ 100 g fresh weight, the minimum value was observed for spinach while maximum was noted for fenugreek leaves. The values for broccoli, cabbage and capsicum were 200.0, 158.6 and 263.8 mg. The available literature reported that vegetables

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Table 1. Overall acceptability of vegetables cooked by three methods for three time periods

Vegetables	Cooking Time (min)	Spinach	Fenugreek	Broccoli	Cabbage	Capsicum
Covered Lid Cooking (CLC)	5 min	5.9	5.25	7.7	3.8	3.7
	10 min	5.7	7.2	6.2	6.5	6.6
	15 min	7.6	6.1	5.5	.4	6.0
Microwaving (MW)	5 min	3.9	6.0	7.4	1.9	3.4
	10 min	5.6	7.7	6.4	5.9	6
	15 min	6.9	6.5	5.8	5.2	4.8
Stir Frying (SF)	5 min	4.6	4.6	7.3	4.2	3.7
	10 min	7.9	6.9	5.9	7.0	7.4
	15 min	7.3	8.0	5.0	6.0	6.7
CD (0.05)		0.9	0.7	0.9	1.1	1.0

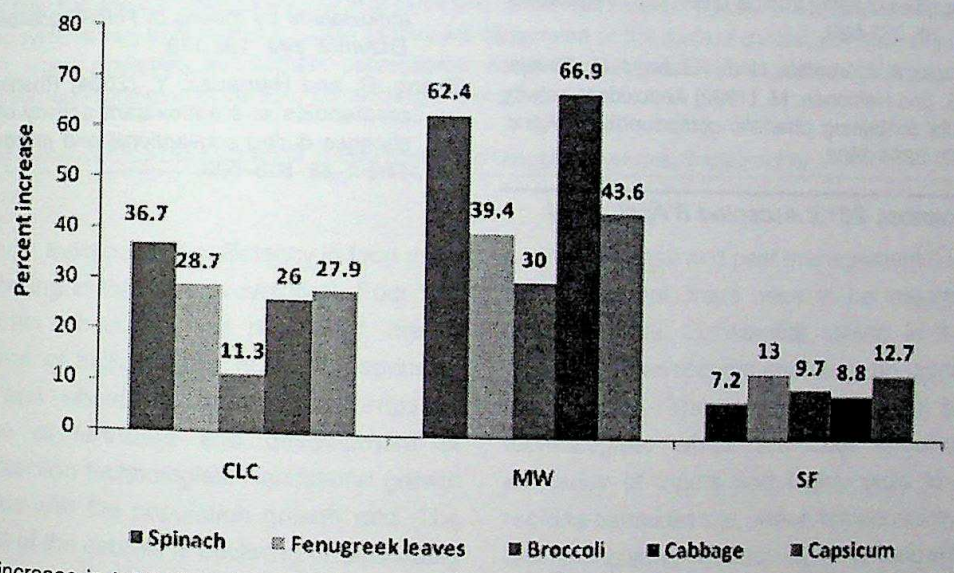

Fig. 1. Per cent increase in total phenol content in selected vegetables cooked by coverlid cooking (CLC), microwave cooking (MW) and stir frying (SF)

are rich sources of total phenols, which possess strong antioxidant activity (Kaur and Kapoor, 2002). Cooking of selected vegetables by three common methods i.e. CLC, MW and SF resulted in an increase of total phenolics (TPC) in case of all the vegetables when the results were expressed on dry matter basis (Fig. 1). MW resulted in maximum increase in TPC (30.0-66.9%) as compared to CLC and SF, while the minimum increase in TPC was during SF in all five vegetables, the range being 7.2 to 13.0%. The maximum increase of TPC during MW was observed in cabbage (66.9%) closely followed by spinach (62.4%) while the least increase was during MW cooking of broccoli (30%). The CLC resulted in maximum and minimum increase of TPC in spinach (36.7%) and broccoli (11.3%), respectively. Other analyzed vegetables also showed lesser increase of TPC during CLC, when compared to SF and MW, the percentage values being 36.7, 28.7, 26.0 and 27.9% for spinach, fenugreek leaves, cabbage and capsicum, respectively.

On comparison of 5 vegetables, CLC resulted in maximum increase of total phenol content (TPC) in spinach (36.7%) while least increase was observed in broccoli (11.3%). During MW, maximum increase was observed in cabbage followed by spinach (62.4%) while least increase was in broccoli (30.0%). Stir frying had least increase, the range being 7.2 to 13.0%, the highest value was for fenugreek leaves while the least was for spinach (Fig. 1). Zhang and Hamauzu (2004) reported that raw broccoli floret contained 34.5 mg/100 g fresh weight of total phenolics and the florets cooked for 5 min by boiling or microwave cooking retained 28.1 and 28.4% of total phenolics, respectively. The results of the present study were in line with those Adefegha and Oboh (2011), who found that the total phenol content of the uncooked leafy vegetables ranged from 146.9 mg/100g to 693.8 mg/100g, while total phenol content of the cooked vegetables ranged from 272.8 mg/100 g to 1037.5 mg/100g. Pellegrini *et al.* (2010) also observed that

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there was an increase in polyphenols after cooking of vegetables. The study concluded that though all methods resulted in an increase in phenolic content but the maximum increase was observed during microwave cooking followed by covered lid cooking, while, the least increase was during stir frying in all the analyzed vegetables. The results indicated that cooked vegetables are an important source of phenolic compounds, hence they are noteworthy contributors of these antioxidant compounds with proven health benefits.

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Efficient Alternate Cropping Systems of India

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Abstract: In order to achieve 4 per cent growth rate in agriculture as envisaged by the Planning Commission, Govt. of India, top priority need to be given to highly productive and profitable cropping systems, which can meet the food demand of burgeoning population and adequate attention has to be paid to remove bottleneck in achieving the growth rate. Cropping system research plays crucial role in crop diversification and intensification by selecting alternative crops, inclusion of catch and cash crops and making best use of leftover of each crop in synergistic manner. The cropping systems vary from region to region as they are designated on the basis of climate, soil type, irrigation facilities, market demand, input supply, labour availability and farmers' perception to adopt the systems. Therefore, all efforts are being made to develop production and protection technologies in all the agro-climatic regions of the country.

Key Words: Cropping Systems, Crop Diversification, Issues Related to Cropping Systems, Sustainability

Undoubtedly, India got self-sufficiency in food grain production the ushering in the green revolution. Four fold increase in foodgrain production was registered, mainly because of evolution of high yielding nutrient responsive varieties of rice and wheat, development of irrigation infrastructure, use of fertilizers and development of production and protection technologies. Agricultural growth could not keep race with the population growth rate. The productivity of most of the cereals is declining or plateauing and the resources are showing the symptoms of fatigue. The fatigue in the post-green revolution ear is now a matter of serious concern. For achieving the required crop production targets to feed more than 1.5 billion in 2050, it is imperative to develop strategies that can sustain higher level of production without an adverse affect on the environment. To maximize the production from available resources and prevailing climatic conditions, need based, location specific technologies needs to be generated.

The self-sufficiency in foodgrain production was achieved at the cost of degradation (physically, chemically and biologically), diminishing biodiversity, depletion of ground water table, increase in environmental pollution, elimination of useful birds on account of high pesticide use and contamination in foods, ultimately affecting the human health. These emerging threats in the irrigated agriculture system have put greater challenge before agricultural scientists to maintain the balance between production and consumption to fulfill the food and nutritional security across the regions and sustainability of resources. The recommendation with regard to important production factors like fertilizer management, water management, weed control, disease and pest management has been formulated for component crops need to be integrated into cropping system mode. Substantial saving in input resources is accrued, when recommendations on cropping system basis are adopted. The main focus should be on to develop technologies, which are cost effective, increase use efficiency of inputs and highly suits to the agro-climatic regions based on soil, water, temperature, rainfall etc. is the first step towards productivity enhancement per unit area.

FAO defined an agro-climatic zone as a land unit delineated in terms of major climate and growing period, which is climatically suitable for certain range of crops/cropping systems and cultivars. Planning commission had identified fifteen resource development regions in the country with fourteen regions in the main land and remaining one in the islands of Bay of Bengal and the Arabian Sea (Gangwar and Singh, 2011). The main objective was to integrate plans of the agro-climatic regions with the state and national plans to enable policy development based on techno-agro-climatic considerations. In the agro-climatic regional planning, further sub-regionalization was possible based on agro-ecological parameters. An agro-ecological zone is a major area of land that is broadly homogeneous in climatic and edaphic factors, but not necessarily contiguous, where a specific crop exhibits roughly the same biological expression. For initiating research in the agro-climatic zones of the country, ICAR launched the National Agricultural Research Project (NARP). In NARP, the country was divided into 126 agro-climatic zones. The description of agro-climatic parameters is needed to determine the potential cropping system within a cropping pattern in a particular area (Table 1).

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Table 1. Important agro-climatic features, soil type and predominant cropping systems of India

S.N.	Agro-climatic region/zone	Rainfall (mm)	Climate	Soils	Predominant cropping systems
1.	Western Himalayan Region	1650-2000	Cold arid to humid and sub-humid	Hills soils, sub-mountain, meadow sheletal	Rice-wheat, maize-wheat and rice-potato-potato
2.	Eastern Himalayan Region	1840-3528	Per humid to humid	Brown hills, acidic soils, alluvial, tarai soils, red sandy, laterite soils	Rice-fallow, rice-rice and rice-pulses/oilseeds
3.	Lower Gangetic Plains	1302-1607	Moist sub-humid to dry sub-humid	Recent alluvial, red, yellow loamy soils	Rice-rice, rice-wheat, rice-potato-jute and rice-potato-vegetable
4.	Middle Gangetic Plains	1211-1470	Moist sub-humid to dry sub-humid	Alluvial, calcareous, tarai soils	Rice-wheat, rice-maize and rice-potato-sunflower
5.	Upper Gangetic Plains	721-979	Dry sub-humid to semi-arid	Alluvial, tarai soils	Rice-wheat, sugarcane-ratoon-wheat, pearl millet-mustard
6.	Trans Gangetic Plains	360-890	Semi-arid to dry sub-humid and arid	Alluvial, calcareous soils	Rice-wheat, cotton-wheat and pearl millet-wheat
7.	Eastern Plateau and Hills	1296-1436	Dry sub-humid to moist sub-humid	Red, yellow, sandy loam to laterite	Rice-black gram/niger/linseed, rice-groundnut and rice- vegetable
8.	Central Plateau and Hills	490-1570	Semi-arid and dry sub-humid	Mixed red and black, medium black , grey, brown and alluvial soils	Maize/sorghum+ soybean-wheat, sorghum+ pigeon pea-Bengal gram/linseed, maize+ soybean-wheat and sorghum-wheat
9.	Western Plateau and Hills	602-1040	Semi-arid to dry sub-humid	Medium to deep black, shallow red loamy soils	Cotton-wheat, sorghum+ soybean-Bengal gram/ durum wheat, pearl millet+ black gram/green gram-safflower
10.	Southern Plateau and Hills	677-1001	Arid, semi-arid to dry sub-humid	Medium to deep black, red sandy to loamy coastal and deltaic alluvium	Sorghum-cotton-groundnut, rice- Bengal gram/green gram, rice-rice, rice-*rabi* maize-fodder
11.	East Cost Plains and Hills	780-1287	Moist sub-humid to semi-arid	Delta coastal alluvial, laterite red and medium black soils	Rice-groundnut-green gram, rice-green gram/ black gram and rice-rice
12.	West Cost Plains and Hills	2226-3640	Per humid to dry humid	Lateritic and coastal alluvium, red loamy soils	Soybean-wheat, cowpea/ groundnut/rice-green gram, cotton+ foxtail millet-green gram, rice-rice
13.	Gujarat Plains and Hills	340-1793	Semi-arid to dry sub-humid	Deep black, coastal alluvium, medium black and brown soils	Castor-chillies-fallow, pearl millet - mustard/ isabgol/cumin, cotton-wheat, pearl millet+ moth/guar-barley-fallow
14.	Western Dry	55-395	Arid to extremely arid	Desert, grey brown soils	Pearl millet+ black gram- mustard, maize+ soybean- durum wheat, groundnut- durum wheat- summer bajra, rice –*rabi* maize/ groundnut- summer moong, cotton-durum wheat
15.	Andaman & Nicobar Islands	1600-3000	Hot per humid	Medium to very deep, red loamy and sandy soils	Rice-fallow

(Source: Gill *et al.*, 2008)

Wide divergence has been noticed with respect to rainfall and soil types in the country and accordingly various cropping systems exist in different agro-climatic zones (Table 1). The constraints in the agricultural production in different agro-climatic regions and their possible ways to overcome have been given in Table 2.

Site-Specific Crop Diversification: Crop diversification in area, where continuous cropping of cereals-cereal systems is in vogue, has been advocated as one of the effective tools for minimizing the second-generation problems and to make a breakthrough in the productivity and profitability. The crop diversification can deliver many agronomic and ecological benefits simultaneously, while maintaining or enhancing the scale of efficiency of production. In this regard, besides adoption of proper input management technologies, diversification of the system through introduction of crops of diverse nature may be a good preposition to break the monotony of the predominant cereal based systems and to sustain productivity over a period of time. For diversification of rice-wheat system, several options are available different zones (Table 3).

Rice, maize, and wheat are major cereals

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Table 2. Constraints limiting the system productivity and future thrust for enhancing yield of various cropping systems in different agro-climatic regions of India

S.N.	Agro-climatic regions/zones	Constraints	Future thrust
1.	Western Himalayan Region	• Fragile ecosystem prone to soil erosion • Low land productivity	Encourage watershed management concept Emphasis on temperate fruits and vegetable crops Promotion of micro-irrigation system under undulated topography of economic value plants/ for providing effective soil cover Need for selection of acid tolerant/ cold resistance crops/ varieties
2.	Eastern Himalayan Region	• Fragile ecology prone to soil erosion with low level of irrigation and recurrent floods • Low productivity	Need to promote integrated watershed management concept Develop pasture based farming system To provide effective soil cover through economic value plants or grasses Rice culture with fishery Discourage jhum cultivation to prove its alternative
3.	Lower Gangetic Plains	• Low productivity level with high population pressure • Poor soil quality • Multi micronutrients deficiency	Development of heat/salinity cultivars for high yield realization Emphasis on rabi maize, boro rice and hybrid rice cultivation Improvement of drainage system Adoption of IPNS
4.	Middle Gangetic Plains	• Low productivity level due to rice - rice monoculture • Poor soil quality • Drainage problem forced maturity of wheat due to high temperature	Crop diversification with emphasis on maize, fruits and vegetable crops Development of heat tolerant short duration wheat cultivars Management of diara and tal areas Amelioration of boron and iron deficiency
5.	Upper Gangetic Plains	• Medium productivity level due to salinity/alkalinity • Unscientific irrigation water use • Availability of inputs • Deteriorating environment with respect to land quality	Selection of salt tolerant crops and varieties Use of amendments which are cost effective Rational use of irrigation water using scientific approach Ensure availability of quality inputs Adoption of new tillage practices for effective crop residue management
6.	Trans Gangetic Plains	• Decline in water table and scarcity of irrigation water • Burning of crop residue • Patches of salinity and alkalinity • Deterioration in soil quality • Poor water quality	Growing crops as per land capability classification Extensive use of zero tillage/ strip till drill Adoption of furrow irrigated raised bed technology in rice -wheat cropping system Crop diversification and intensification Delineation and mapping of multi-nutrient deficiency Promotion of integrated nutrient management for taking care of soil health
7.	Eastern Plateau and Hills	• Low productivity • Soil, water erosion and ruoff • Depending on rainfall	Watershed management concept need to encouraged Need to follow integrated farming system with goatry, cattle, piggery and poultry Enhancing cropping intensity with vegetable crops
8.	Central Plateau and Hills	• Lack of irrigation facilities • Very low productivity with subsistence farming • Excessive runoff • Under utilize potential of horticulture and livestock • Natural stress like drought, etc are very common	*In situ* water harvesting and recycling Development of abiotic tolerant varieties of rice, wheat, pulses and oilseeds Use of mulches for water conservation Promotion of agro-forestry, silvi-pastoral and agri-horti system Diversification of small millets with high values crops in different cropping systems
9.	Western Plateau a nd Hills	• Growing low value cereal crops • Poor irrigation facility • Runoff and soil erosion • Soils with high clay content with low drainability	Inclusion of high value crops (medicinal and aromatic crops) in different cropping systems Promotion of agri-horti-pastoral farming system Development of water shed
10.	Southern Plateau and Hills	• Large rainfed area • Tank led irrigation • Large scale cultivation of low value cereals • Poor quality water	Water harvesting and recycling Selection of crops, which can tolerate abiotic stress particularly water stress Selection of crops/varieties tolerant/semi tolerant to salts
11.	East Cost Plains and Hills	• Fragile ecology due to water logging, salinity/acidity and soil erosion • Rainfed area led with tank irrigation	Develop technology for Makhana/Sanghar cultivation Development of prawn/fishery based cropping system Need to develop agronomic manipulation to counteract flooding conditions

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12.	West Cost Plains and Hills	• Excessive runoff/soil salinity/ acidity/irregular stretches of back water • Inadequate drainage • Poor quality water	Development of salt tolerant varieties of rice, sugarcane, foxmillet Reclamation of degraded land Develop for prawn based farming system in brackish water Preference to low water requiring crops during non-rainy season
13.	Gujarat Plains and Hills	• Dependent on rainfall with frequent weather aberration • Depletion of ground water • Reducing forest cover • Water logging in canal areas	Developing abiotic stress resistant varieties of rice Water harvesting and recycling Developing early hybrids of bajra Encouraging intercropping with groundnut and cotton
14.	Western Dry	• Hot climate arid conditions • Fragile ecosystem • Poor land quality	*In situ* water harvesting/ conservation through adoption of cultural practices like ridge furrow planting, intercropping/mixed cropping with legume, soil mulch Development of extra short hybrids of bajra Integrated farming system with a component of crops, livestock, silvi-pastoral system, agri -horti system, agri -horti-silvi-culture to sustain arid ecosystem

(Source: Gill *et al.*, 2008)

Table 3. Efficient crop diversification options for rice-wheat farmers

Cropping system K – R – S	REY (t/ha/yr)	Productivity (kg/day/ha)	Profitability (Rs./ha/day)	NUP (kg grain/kg nutrient use)
South Alluvial Plain zone of Bihar				
Rice-Wheat	7.7	21.1	38.6	21.4
Rice-Garlic-Maize	11.2	30.6	76.4	23.7
Mid high altitude intermediate zone of J&K				
Rice-Wheat	9.2	25.3	87.4	26.4
Rice-Cauliflower-French bean	11.0	30.1	93.8	53.2
Central plain zone of Punjab				
Rice-Wheat	11.0	30.0	33.0	25.1
Maize-Potato-Onion	18.2	50.0	84.2	45.1
Central plain zone of U.P.				
Rice-Wheat	8.8	240.	36.4	28.1
Maize-Potato-Sunflower	15.3	41.9	56.4	20.5
Vindhyan plain zone of U.P.				
Rice-Wheat	8.5	23.2	32.3	17.7
Rice-Potato-Green gram	14.3	39.2	58.2	22.2
Bhabar and Tarai zone of Uttarakhand				
Rice-Wheat	11.9	32.7	91.5	23.9
Rice-Rapeseed-Sunflower	12.6	34.5	93.1	23.1
Plain zone of Chattisgarh				
Rice-Wheat	8.6	23.7	90.2	32.0
Rice-Brinjal-Green manure	10.7	29.4	112.4	54.0
Plateau and Satpura hill zone of M.P.				
Rice-Wheat	6.7	18.4	53.7	16.7
Rice-Berseem(f)-Berseem (S)	10.5	28.7	103.3	47.7
South Gujarat heavy rainfall zone				
Rice-Wheat	6.9	18.9	48.3	20.9
Rice-Onion-Veg. cowpea	8.6	23.5	52.2	22.0
Vindhyan Plateau zone of M.P.				
Rice-Wheat	5.4	14.6	33.4	14.1
Rice-Berseem(f)-Berseem (S)	7.2	19.6	62.4	23.8
Eastern plain zone of U.P.				
Rice-Wheat	7.1	19.4	37.0	15.9
Rice-Potato-Green gram	15.5	42.3	97.9	11.5

(Source: Gangwa *et al.*, 2011) K= *Kharif*, R= *Rabi*, S=summer, REY = rice equivalent yield, NUP = nutrient use productivity

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contributing to food security and income in South Asia. These crops are grown either as a monoculture or in rotations in tropical and sub-tropical environments of South Asia (Ttable 4). In the irrigated and favorable rainfed lowland areas, rice-rice, rice-wheat, and rice-maize are the predominant cropping systems. Rice-rice is common in tropical climate with distinct dry and wet seasons such as in South India, and in sub-tropical areas with mild cool winter climate such as in Bangladesh, Eastern India, and Eastern Nepal. Rice-wheat systems are extensive in the sub-tropical areas of the Indo-Gangetic Plains (IGP) of Bangladesh, India, Nepal, and Pakistan, while Rice-Maize systems exist in all climate ranging from tropical to sub tropical to warm temperates (Timsina *et al.*, 2010). Rice-maize systems, however, are less extensive as compared to Rice-Wheat or Rice-Rice if total area under these cereal systems is considered.

Rice-wheat is the most predominant cropping system of Punjab. The wide adoption of rice-wheat system is mainly due to its high productivity,stability and less risk. Although the system has sustained over years but the yield shows stagnation since early 1990's. This stagnation may be due to appearance of new biotypes (hardy weeds), deterioration of physical properties of soil, formation of hard pan beneath plough layer, development of hardy and reisitant weeds, increase in insect-pest and diseasea, exhaustive nature of both the crops. For diversification of rice-wheat system, several options are available (Yadav *et al.*, 1998, Gangwar and Ram 2003, Katyal *et al.* 2002). The inclusion of crops like oilseeds, pulse and vegetable will improve the economic condition of the farmers owing to higher price and higher volume of their main and by- products. The legumes has also shown the favourable effect on the soil health. The maize-potato-wheat; summer groundnut-potato-pearl millet (f) and maize-potato-summer moong bean produced significantly higher rice equivalent yield as 22.5, 15.8 and 15.8 t/ha/year against 14.2 t/ha/year in rice-wheat system which cleary elucidated the superiority of these system over rice-wheat system (Walia *et al.*, 2010). Mandal *et al.* (2011) conducted an experiment for economic analysis of different diversified rotational cropping systems under Farmers' package/practices and improved package/practices in Birbhum district, West Bengal, located in the red and lateritic belt of lower Gangetic plainof eastern India. The results thus revealed that diversified cropping systems (peanut-brinjal-brinjal, rice-potato-pumpkin, and cucumber-cabbage-basella) required higher cost for cultivation, but also produced higher rice equivalent yield, higher net return and higher return per rupee invested in both management practices. Considering the resource-ability and risk-bearing capacity, and net return and return rupee^{-1} (RPR) invested, these cropping systems can be recommended for resource-rich farmers. Rice-rapeseed-cowpea, rice-wheat-green gram and radish-tomato-amaranthus systems required less inputs for cultivation, were less risky, and economically viable and profitable. These cropping systems can be recommended for resource-poor farmers. Peanut-brinjal + brinjal-okra-chilli + chilli-cucumber-cabbage-basella system was the best among all the 3-year rotational systems in respect to RPR (return rupee^{-1}) in both management practices.

Singh *et al.* (2003) reported that clusterbean-wheat is more economical than cowpea-wheat and pearl millet-wh eat crop sequences in parts of Rajasthan. With assured availability of irrigation, cottton-groundnut for Vidarbha and central Maharashtra plateau zones, and sugarcane-based cropping systems for western Maharashtra scarcity zone were found to be more productive, profitable and efficient (Gangwar *et al.*, 2003). Gangwar *et al.* (2004) reported that under limited irrigation water situations of Vindhyan plateau zone of Madhya Pradesh, soybean-based systems *viz.* soybean-wheat and soybean-chickpea systems were identified to be more efficient only in term of production (5128 and 4990 kg/ha/year as wheat grain-equivalent yield), productivity (14.50 and 13.67 kg/ha/year) and stability (0.56 and 0.62), but, in terms of economic viability, blackgram-linseed and maize-linseed were more viable in terms of net

Table 4. Area (Mha) under major cropping system in four South Asian countries

Cropping system	Area (Mha)			
	Bagladesh	India	Nepal	Pakistan
Rice-Rice	4.50	4.70	0.30	
Rice-Rice-Rice		0.04		
Rice-Wheat	0.30	9.20	0.57	2.20
Rice-Maize	0.40	0.53	0.43	
Maize-Wheat	0.35	1.80	0.04	1.00
Rice-Pulses		3.50		
Rice-Vegetable		1.40		
Millet-Wheat		2.44		

(Source: Timsina *et al.*, 2010)

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return and benefit: cost ratioon. In mid high altitude of Jammu rice-wheat-sorghum + cowpea fodder system was identified be most productive with rice equivalent yield of 11835 kg/ha/year and yield stability of 0.45 (Gangwar *et al.,* 2006). The next best seuence was rice-mustard-greengram with 11221 kg/ha/year rice-equivalent yield and yield stability of 0.42. these systems were distinctly better than existing rice-wheat offering an opportunity to diversify the existing system.

Effective nutrient management is essential to sustain any cropping system over years. To check or reverse the present declining trend in factor productivity, it is essential to follow system-based integrated nutrient management approach. In fact site specific nutrient management approachb to achieve targeted yield is being focussed in recent years (Shukla *et al.,* 2004). Nutrient management based on system basis, rather than to indivisual crop, leads to higher efficiency and economics besides system sustainability (Hegde and Babu, 2002). Recent studies on loamy sand soils at Ludhiana have shown that the best approach for P management in rice-wheat system is to apply recommended doses of phosphorus to both the crrops (Singh *et al.,* 2002). Ali *et al.* (2012) compared the Seven cropping patterns *viz;* rice-berseem, rice-lentil, rice-canola, rice-wheat-mungbean, rice-wheat-cowpeas, rice-sunflower and rice-wheat-sesbania (rostrata) with commonly practiced rice-wheat cropping pattern. The cropping systems were evaluated for their productivity & to assess their effect on the soil organic carbon contents and available soil NPK. The results revealed that the green manuring and leguminous cropping patterns gave higher paddy yield as compared to commonly practiced rice-wheat cropping pattern. The maximum paddy yield of rice (3.73 t/ha) was obtained from rice-wheat-sesbania cropping pattern where sesbania was sown and incorporated in the soil as green manuring crop just before rice transplanting. This increase in paddy yield was statistically at par with the paddy yields received from rice-wheat-mungbean (3.57 t/ha) and rice-berseem (3.52 t/ha) cropping pattern. The yield of succeeding wheat crop was also higher in case of green manuring (sesbania) and leguminous crops (mungbean and cowpeas) which yielded 2.81, 2.69 and 2.63 t/ha respectively. The yield in case of rice-wheat cropping pattern was only 2.59 t/ha. As regards cost benefit ratio, the highest ratio was received in case of rice-lentil (1:2.38) cropping system followed by rice-canola (1:1.96) and rice-wheat-mungbean (1:1.78) as against the existing cropping pattern (rice-wheat) which gave the ratio (1:1.56). The results further indicated that introduction of green manuring or leguminous crops in the existing rice -wheat system not only increased grain yields but also improved the physio-chemical properties, organic matter contents and nutrients availability in the soil. Increase of NPK over initial soil fertility was N (0.12 %), P (2.8 ppm), and K (52 ppm). Soil pH lowered from 8.2 to 7.8 and organic carbon increased from 0.67 % to 0.72 %. Gangwar and Ram (2005) revealed that the population of *Phalaris minor* in wheat could be reduced through inclusion of vegetable pea as catch crop before wheat and interruptive cropping of mustard instead of wheat (once in 3 years). The soil fertility (Organic carbon, N, P, K and S) in general could be maintained or enhanced in cropping sequences involving vegetable pea, greengram or interruption of wheat through mustard and rice through maize and pigeon pea once in three years.

Specific Issues Relating to Some Important Cropping Systems

Rice-Wheat

Rice-Wheat system is the most widely adopted cropping system in the country and has become mainstay of cereal production. The states of Uttar Pradesh, Punjab,Haryana, Bihar, West Bengal and Madhya Pradesh are now the heart land of rice-wheat cropping system with an estimated area of 10.5 million hectares. Despite enormous growth of this cropping system in the country during the past few years, reports of stagnation in the productivity of these crops, with possible decline in production in future, have raised doubts on its sustainability. Important issues emerging as a threat to the sustainability of rice-wheat system are:

- Over mining of nutrients from soil,
- Disturbed soil aggregates due to puddling in rice
- Decreasing response to nutrients
- Declining ground water table
- Build up of diseases/pests
- Build up of *Phalaris minor*
- Low input use efficiency in north western plains
- Low use of fertilizer in eastern and central India
- Lack of appropriate varietal combination
- Shortage of labour during optimum period for transplanting paddy.

Rice-Rice

Rice-rice is the popular cropping system in irrigated lands in humid and coastal ecosystems of Orissa, Tamil Nadu, Andhra Pradesh, Karnataka and Kerala and it is spread over an area of six million hectares. The major issues in sustaining productivity of rice-rice system are:

i. Deterioration in soil physical conditions.

ii. Micronutrient deficiency

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iii. Poor efficiency of nitrogen use.
iv. Imbalance in use of nutrients.
v. Non-availability of appropriate transplanter to mitigate labour shortage during critical period of transplanting.
vi. Build up of obnoxious weeds such as *Echinochloa crusgalli* and non-availability of suitable control measures.

In Kerala, reduction in area is mainly attributable to the conversion of paddy lands to more profitable and less labour intensive plantation estates. In Assam, low productivity under prevailing soil and climatic situations, poor drainage in submerged areas, low nutrient use and iron toxicity are some of the issues of concern. The other general issues of low productivity are build up of pests, diseases and weeds year after year and deterioration of soil health to a large extent.

Cotton-Wheat

Cotton is widely grown in alluvial soils of north India (Punjab, Haryana, Rajasthan and Western Uttar Pradesh) and black cotton soils of central India (Andhra Pradesh, Tamil Nadu and Karnataka). With the availability of short duration varieties of cotton, cotton-wheat cropping system has become dominant in North. About 70-80 per cent area of cotton is covered under this system. In Central region also, wherever irrigation is available, cotton-wheat is practiced. The major issues of concern in cotton-wheat cropping system are:

i. Delayed planting of succeeding wheat after harvest of cotton.
ii. Stubbles of cotton create problem of tillage operations and poor tilth for wheat.
iii. Susceptibility of high yielding varieties of cotton to boll worm and white fly and consequently high cost on their control leading to unsustainability.
iv. Poor nitrogen use efficiency in cotton results in low productivity of the system.
v. Appropriate technology for intercropping in widely spaced cotton is needed to be developed.

Sugarcane-Wheat

Sugarcane is grown in about 3.4 million hectare. In north India (Uttar Pradesh, Punjab, Haryana and Bihar), which account for 68 per cent of the total area under sugarcane, sugarcane-ratoon-wheat is the most important crop sequence. The system is also gaining importance in Jorhat, Sibsagar and Sonitpur districts of Assam; Ahmedanagar and Kolhapur district of Maharashtra and Belgaum district of Karnataka. The other states where the system covers considerable area under sugarcane-wheat are Haryana, Punjab, Madhya Pradesh and Rajasthan. Problems in sugarcane-wheat system are:

i. Late planting of sugarcane as well as wheat.
ii. Imbalance and inadequate use of nutrients. Since majority of farmers apply only N in sugar cane and the use of P and K is limited. The emerging deficiencies of P, K, S and micro-nutrients are limiting system productivity directly and through interactions with other nutrients.
iii. Poor nitrogen use efficiency in sugarcane.
iv. Low productivity of ratoon due to poor sprouting of winter harvested sugarcane in north India.
v. Build up of *Trianthema partulacastrum* and *Cyprus rotundus* in sugarcane.
vi. Stubble of sugarcane pose tillage problem for succeeding crops and need to be managed properly.

Maize-Wheat

Among maize-wheat growing areas, maize is the principal crop of *Kharif* season in northern hills of the country but plains of northern states like Uttar Pradesh, Rajasthan, Madhya Pradesh and Bihar also have sizeable acreage under this crop. Results of national demonstrations and lab to land demonstrations clearly revealed that this system has a potential to produce 8-10 t/ha per year. However, experimental findings from various research stations revealed that a productivity of more than 10.5 t/ha per year (6.0 t+ 4.5t) may be realized under sub-montane conditions of Jammu. Likewise, a productivity of 7-8 t/ha per year at Palampur, 6.28 t/ha per year (2.00 + 4.28 t) at Indore and more than 7 t/ha per year at Ludhiana has been recorded in maize-wheat system. Maximum yield research in maize-wheat sequence at Palampur has shown a potential of 14.21 t/ha per year by optimization of various resources like plant population, manures and fertilizers.

Poor maize-wheat yield has been reported from Andhra Pradesh, Assam, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Tripura, Eastern Uttar Pradesh and Tamil Nadu. There are number of reasons for poor but the most significant are:

1. Sowing time
2. Poor plant population
3. Poor weed management
4. Poor use of organic and inorganic fertilizers.
5. Large area under rain fed.

Declining yield trends in maize-wheat system under long term experiments have indicated that the system suffers due to emerging deficiencies of multiple nutrients. Continuously over-mining of nutrients from soil and imbalance on use of fertilizers in maize-wheat system are some of the many reasons for such decline.

Soybean – Wheat

Soybean-wheat cropping system has emerged as an important cropping system only after 1980 with the introduction of soybean as a *Kharif* crop in wheat growing

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areas of the country particularly under irrigated ecosystem.

Constraints limiting the soybean production and productivity *viz*. a relatively recent introduction of soybean as a crop, limited genetic diversity, short growing period available in Indian latitudes, hindered agronomy/availability of inputs at farm level, rain fed nature of crop and water scarcity at critical stage of plant growth, insect pests and diseases, quality improvement problems, inadequate mechanization and partial adoption of technology by farmers have been identified.

The realized and realizable yield potential have shown that the nation-wide average realized yield obtained by adopting improved technology is about 2 t/ha in soybean as against one t/ha obtained under farmers' practices. It is, however, to be noted that yield level of 3 to 3.5 t/ha in individual farmer's fields is not so uncommon in southern Maharashtra, Malwa plateau and some areas of Rajasthan.

Legume Based Cropping Systems

Legume crops (pulses and oilseeds) are popular for their suitability in different cropping systems. Recent advances in the development of large number of varieties of pulse and oilseed crops, varying largely for maturity duration, have made it possible to include them in irrigated crop sequences. The popular cropping systems are pigeon pea-wheat in Madhya Pradesh and groundnut-wheat in Gujarat, Maharashtra and Madhya Pradesh and groundnut-sorghum in Andhra Pradesh and Karnataka.

The major issues in legume based cropping systems are:

i. No technological breakthrough has been achieved so far in respect of yield barriers, particularly in legumes.
ii. Susceptibility of the pulses to aberrant weather conditions especially water logging and adverse soils making them highly unstable in performance.
iii. High susceptibility to diseases and pests.
iv. Low harvest index, flower drop, indeterminate growth habit and very poor response to fertilizers and water in most of the grain legumes.
v. Nutrient needs of the system have to be worked out considering N-fixation capacity of legume crops.

Future thrust

i. Water will be a scarce resource in future. Therefore, most efficient cropping systems for quantified water availability conditions need to be identified.
ii. Inputs becoming more costly every year resulting increase in cost of crop production. Therefore, *in situ* supplementation of inputs would be helpful. As such, bio-intensive complementary cropping systems need to be identified for partial *in situ* management of nutrients and pests.
iii. Diversification effects through inclusion of spices, medicinal and aromatic and horticultural crops with reference to productivity, profitability, stability and soil health in rice-wheat systems need to be quantified at different locations.
iv. Both short and long-term strategies need to be worked out considering the present trends and future perspectives of globalization of economy with new trade opportunities.
v. Development of synthesized sustainable cropping system models need to be attempted to achieve desirable change in the existing systems.
vi. Location specific resource management strategies need to be worked out for different crops and cropping systems so as to achieve quantum jumps in crop production.

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On-Farm Evaluation of Various Rice (*Oryza sativa*) Based Cropping Systems to Improve Profitability and Resource Use Efficiency in Coastal Saline Zone of West Bengal

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Abstract: A farmers' participatory field experiment with four different rice-based cropping systems was conducted during 2011-12 and 2012-13 in coastal saline zone of West Bengal. Due to low land agro-ecosystem, conventionally farmers grow long duration high yielding varieties of rice during wet season and keep their land either fallow or marginally growing some low water requiring crops in dry season (*rabi* and summer) using residual moisture or life saving irrigation. This study was aimed to evaluated profitability and resource use efficiency of rice-greengram, rice – sunflower, rice – sunflower + greengram and rice – lady's finger cropping systems. Rice – lady's finger cropping system recorded significantly higher yield of rice grain (4,617.04 kg ha^{-1}) and straw (6,605.11 kg ha^{-1}), system equivalent yield (28,080.17 kg ha^{-1}) and productivity (78.01 kg ha^{-1} day^{-1}). The highest net return (₹1,44,600 ha^{-1}) and B:C ratio (2:24) were also obtained in rice – lady's finger cropping system, followed by rice – sunflower. Rice – sunflower cropping system recorded significantly higher phosphate and potash uptake, however, regarding nitrogen uptake the same was at par with rice – lady's finger system. Higher land use efficiency, irrigation water use efficiency, energy output and employment generation were registered with rice – lady's finger system followed by rice – sunflower.

Key Words: Cropping System, Coastal Saline Zone, Employment Generation, Energy Output

There are mainly six agro-climatic sub-regions in West Bengal state, namely: i) the Northern hilly zone, ii) the Terai-Teesta flood plain, iii) the Gangetic flood plain, iv) the Coastal flood plain, v) the Vindhya old flood plain and v) the undulating Lateritic sub-regions of the Eastern Plateau Region (Sengupta, 2001). Out of these six agro-climatic regions, the Coastal flood plain is one of the most constrained zone, comprising of whole south 24 Parganas district and part of north 24 Parganas, Howrah and East Midnapore districts. This area represents low land agro-ecosystem with heavy textured saline soils, limited availability of irrigation water and very low cropping intensity (134%) as compared to state average of 185%. Conventionally, farmers grow high yielding rice varieties during wet season and use to keep their land fallow in dry season (*rabi* and summer) except marginally growing some low water requiring crops like greengram, lathyrus etc. using residual moisture or life saving irrigation. Water harvested in small tanks is the only source of irrigation during dry period. Though most of the farmers are resource poor, but this area is well connected by rail and road facility, favouring better marketing of their produce. Diversification of cropping system with food crops like potato, oilseed and vegetables is necessary for obtaining higher yield and return, maintenance of soil health, protection of environment and meeting up daily requirement of human and livestock (Samui *et al*., 2004). Inclusion of legumes in the cropping system increases soil fertility status (Ghosh, 1987; Upadhyay *et al*., 2011). By and large a number of soil and climatic parameters decide cropping system of a region, which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Choice of crop or cropping system is further narrowed down by several forces regarding infrastructure facilities, socio-economic factors and technological development which are operating interactively at micro-level. Potential productivity and monetary benefit act as guiding principles for a particular crop / cropping system, at farmers' level.

Mostly the scientists and extension workers simply do not have definite answers to the problems faced problems by the stakeholders (farmers) in an uncertain and ever-changing environment. This condition provides the opportunity for a new era in agricultural research and development, where scientists, extension workers and farmers can learn together how to best manage the agriculture in a sustainable manner. In general, in the process of technology assessment farmers' concern like their resources, social and economic aspect as well as their

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perception were often ignored, particularly in case of the resource poor farmers. As a result the potential yield and profitability of a crop/cropping system remains far behind from that of actual. Farmers' participatory research (FPR) emphasizes the process that enables a local farmer to evolve and promote improved agricultural technologies to the field. It values scientists and farmers knowledge equally and underlines the complementary nature of both pools of knowledge in generating and using technologies. Considering this fact, a participatory research was conducted to evaluate the productivity, profitability and resource efficiency at farmer field representing coastal flood plains of West Bengal. The objectives of the present study were to assess productivity, profitability, resource efficiency and energy efficiency of different rice-based cropping systems at farmers' level through farmers' participatory approach.

MATERIAL AND METHODS

A field experiment was conducted at farmers' field in two blocks (Mandirbazar and Kakdwip) of 24 Paraganas (South) district of West Bengal adopted by AICRP on Integrated Farming Systems, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia during two consecutive years 2011-12 and 2012-13 with four rice-based cropping systems. In each block, there were three villages and in each village there were four farmers' field *i.e.* in total there were twenty four numbers of farmers' field. These farmers' fields lie between 21°50.068'N to 22°06.975' N latitude and 88°11.858' E to 88°19.653' E longitude with an average altitude of 8.18 m above mean sea level in coastal saline flood plain of West Bengal. The cropping systems of the experiment were: Rice – Greengram; Rice – Sunflower; Rice – Sunflower + Greengram (2 : 4) and Rice – Lady's finger. Crop sowing window period, harvesting window period, recommended fertilizer dose and variety of different crops under all cropping systems are given in Table 1. Recommended doses of N, P and K were applied to different crops through urea, single super phosphate and muriate of potash, respectively. Irrigation water is the most scare and limited resource during dry period for crop cultivation in this area. *Kharif* rice was grown under rain fed condition. Limited amount of irrigation water at critical growth stage was given to all the dry period crops and total depth of irrigation was calculated for each of the crop, in turn for all the cropping systems. The need based intercultural and plant protection measures were adopted for different crops. The average values of soil properties as well as ranges of experimental fields were: pH 5.43 (4.45-6.99), EC 0.58 (0.15-1.95) dS m^{-1}, organic carbon 0.71 (0.58-0.82)%, available N 140.46 (111.09-186.55) kg ha^{-1}, P 48.07 (39.88-59.82) kg ha^{-1} and

Table 1. Date of sowing, date of harvesting, fertilizer dose and variety of the different crops of the crop sequences

Cropping sequence	Parameters	2011-12		2012 -13	
		Kharif	Summer	*Kharif*	Summer
Rice-Greengram	Sowing window	Last week of June	2nd fortnight of January	Last week of June	2nd fortnight of January
	Harvesting window	Last week of November	2nd fortnight of April	Last week of November	2nd fortnight of April
	Fertilizer dose	80:40:40	20:40:40	80:40:40	20:40:40
	Variety	IET-5656	Local	IET-5656	Local
Rice-Sunflower	Sowing window	Last week of June	1st fortnight of January	Last week of June	1st fortnight of January
	Harvesting window	Last week of November	1st fortnight of May	Last week of November	1st fortnight of May
	Fertilizer dose	80:40:40	80:40:40	80:40:40	80:40:40
	Variety	IET-5656	GK-2002	IET-5656	GK-2002
Rice-Sunflower+Greengrm (2:4)	Sowing window	Last week of June	1st fortnight of January	Last week of June	1st fortnight of January
	Harvesting window	Last week of November	1st fortnight of May	Last week of November	1st fortnight of May
	Fertilizer dose	80:40:40	80:40:40	80:40:40	80:40:40
		IET-5656	Local/ GK-2002	IET-5656	Local/ GK-2002
	Variety				
Rice-Lady's finger	Sowing window	Last week of June	1st fortnight of January	Last week of June	1st fortnight of January
	Harvesting window	Last week of November	2nd fortnight of May	Last week of November	2nd fortnight of May
	Fertilizer dose	80:40:40	80:40:40	80:40:40	80:40:40
	Variety	IET-5656	Pankaj	IET-5656	Pankaj

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available K 305.84 (281.45-324.67) kg ha^{-1}. The area received an annual rainfall of 1626 cm and 1667 cm in the year 2010-11 and 2012-13, respectively.

All the four cropping systems were allotted in each of the farmer's field taking a block of 100 m^2 area i.e. the area of each cropping system at every farmer's plot was 25 m^2. The experiments were conducted at same site during the entire period of study and each farmer's field was treated as one replication. The observations on yield and other parameters were taken and analysed following Gomez and Gomez (1984). The cost of cultivation was calculated on the basis of prevailing market price of different inputs used for each cropping system. The prevailing farm gate price at the time of harvest were used for rice grain and straw, sunflower seed, greengram and lady's finger. The monetary return for the cropping systems was calculated on yearly basis. To compare among the cropping systems, the economic yield of component crops was taken into account over the year and converted into rice equivalent yield (REY) on price basis for each cropping system (Verma and Mudgal, 1983). The land use efficiency (LUE) was calculated from total duration of crops in the cropping system divided by 365. The total economic yield in terms of REY of a cropping system was divided by 365, to get the system productivity (kg $ha^{-1}day^{-1}$) (Devasenapathy *et al.*, 2008). Net return was worked out by the difference of gross returns and total cost of cultivation of a system. B:C ratio (Returns per rupee invested) of a system was expressed as net returns (₹) per ₹ spent. Economic efficiency in terms of ₹ ha^{-1} day^{-1} was worked out by dividing the net returns of the system by total duration of crops in a system in an agricultural year (Patil *et al.*, 1995). The irrigation water use efficiency of a system refers to the economic yield obtained, in terms of REY, due to use of per unit of irrigation water. The energy output of different systems was calculated on the basis of economic yield as given by Mittal and Dhawan (1988) and expressed as the total energy (MJ/ha).

RESULTS AND DISCUSSION

Productivity: The yield of *kharif* season rice crop was higher at second block (Kakdwip) (4627.52 kg ha^{-1}) as compared to first block (Mandirbazar) (4473.98 kg ha^{-1}). The same block also recorded significantly higher straw yield (6546.02 kg ha^{-1}).This may because of better soil fertility of second block. The pooled analysis revealed that rice crop registered highest yield in terms of grain (4617.04 kg ha^{-1}) as well as straw (6605.11 kg ha^{-1}) in rice-lady's finger cropping system, which was significantly higher than the other crop sequence and was followed by rice-greengram+sunflower, rice-sunflower and rice-green gram. In rice-lady's finger sequence rice yield was 2.8%, 1.9% and 1.1% more than rice-greengram, rice-sunflower and rice-sunflower+greengram respectively. Maximum rice equivalent yield (REY) (15,937.28 kg ha^{-1}) and system productivity (44.45 kg ha^{-1} day^{-1}) were recorded with second block, which showed 15.82% and 18% higher REY and productivity respectively over second block. Rice-lady's finger crop sequence was found most productive in terms of REY (28,080.17 kg ha^{-1}) and productivity (78.01 kg ha^{-1} day^{-1}), followed by rice-sunflower, rice-greengram+sunflower and rice-greengram. Rice-lady's finger sequence recorded 220.7, 163.28 and 190.61 percent higher REY than rice-greengram, rice-sunflower and rice-greengram+sunflower sequence, respectively. Regarding productivity rice-lady's finger sequence registered 224.37, 164.62 and 192.83 percent higher values than rice-greengram, rice-sunflower and rice-greengram+sunflower sequence, respectively (Table 2). The system containing lady's finger, rice yield was significantly higher due to residual effects of high doses of fertilizer and organic manure applied to lady's finger may have caused benefits for rice, as has also been observed in other studies with potato and lady's finger (Ray *et al.*, 2009 and Samui *et al.*, 2004).

Profitability: Both production cost and annual net return must be considered for choosing suitable cropping systems for the coastal saline flood plain of West Bengal because those varied widely among individual cropping systems. Production cost for rice-lady's finger cropping system was observed highest (₹1,17,780 ha^{-1}), followed by rice-sunflower (₹59,440 ha^{-1}), rice-greengram+sunflower (₹56,280 ha^{-1}) and rice-greengram (₹53,120 ha^{-1}). Inclusion of lady's finger in cropping system resulted in significantly higher production cost than any other crops, primarily due to high cost of labour, fertilizers, plant protection chemicals and irrigation (Table 3). Singh *et al.*(2013) reported that the rice-lentil and rice-pea crop sequence required less cost of cultivation in comparison to rice-frenchbean or rice-mustard sequence. Marginally higher cost of production was recorded in Mandirbazar block (₹70,880 ha^{-1}) than Kakdwip block (₹70,780 ha^{-1}) due to comparatively higher labour cost (Table 3).

Net returns were directly related to the price that the producer received for the produce and inversely related to the production cost. Though growing lady's finger was associated with highest production cost, it was also the most profitable crop. Both net return and B:C ratio were highest for lady's finger as well as for lady's finger containing cropping system (₹1,44,600/- and 2.24), followed by sunflower and

Table 2. Rice grain and straw yield, system rice equivalent yield and system productivity

Treatment	Rice grain yield (kg ha^{-1})	Rice straw yield (kg ha^{-1})	System rice equivalent yield (kg ha^{-1})	System productivity (kg ha^{-1} day^{-1})

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Table 2. Rice grain and straw yield, system rice equivalent yield and system productivity

Treatment	Rice grain yield (kg ha^{-1})			Rice straw yield (kg ha^{-1})			System rice equivalent yield (kg ha^{-1})			System productivity (kg ha^{-1} day^{-1})		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
Block 1	4553.05	4394.92	4473.98	6623.71	6315.55	6469.63	49391.04	12363.58	12643.90	35.41	33.87	34.64
Block 2	4645.11	4609.92	4627.52	6559.95	6532.09	6546.02	79585.44	14122.73	15937.28	50.21	38.69	44.45
SEm (±)	15.23	16.06	11.06	23.83	24.93	17.24	1627.21	88.23	161.62	0.55	0.24	0.30
CD(0.05)	42.99	45.34	30.66	67.29	70.40	47.79	4594.83	249.15	447.93	1.54	0.68	0.83
Cropping Systems												
R-G	4541.57	4439.55	4490.56	6512.29	6339.27	6425.78	9048.04	8460.79	8754.42	24.92	23.18	24.05
R-S	4583.58	4476.38	4529.98	6566.26	6388.76	6477.51	11375.71	9954.96	10665.33	31.69	27.27	29.48
R-S+G	4612.73	4518.10	4565.41	6610.35	6435.44	6522.90	10017.00	9307.88	9662.44	27.78	25.50	26.64
R-L	4658.42	4575.65	4617.04	6678.41	6531.81	6605.11	30911.33	25249.00	28080.17	86.85	69.18	78.01
SEm (±)	21.53	22.71	15.65	33.70	35.26	24.39	439.78	124.78	228.57	0.77	0.34	0.42
CD(0.05)	60.80	64.12	43.36	95.16	99.56	67.59	1241.84	352.35	633.47	2.18	0.97	1.17

R-G: Rice-Greengram, R-S: Rice-Sunflower, R-S+G: Rice-Sunflower+Greengrm (2:4), R-L: Rice-Lady's finger

greengram containing system respectively (Table 3). This is mainly due to higher yield of lady's finger. Rice-lady's finger system recorded 400, 258 and 322 per cent higher net returns than rice-greengram, rice-sunflower and rice-greengram+sunflower systems, respectively. Rice-lady's finger system also recorded 44.52, 31.76 and 38.27 per cent higher B:C ratio than rice-greengram, rice-sunflower and rice- greengram+sunflower systems, respectively. The results of this experiment confirm the findings of Ray *et al.,* 2009 and Samui *et al.,* 2004. Among the two blocks, significantly higher net return (₹75,010/-) and B:C (1.91) were recorded in Kakdwip block than Mandirbazar mainly due to higher yield and less cost of production.

Nutrient Uptake: Among the different cropping systems, rice-lady's finger registered the highest N uptake (₹324.93 kg ha^{-1}) followed by rice-sunflower (₹320.89 kg ha^{-1}) and rice-greengram+sunflower (₹316.28 kg ha^{-1}) and those were found statistically at par, whereas rice-sunflower system recorded the highest P (₹66.62 kg ha^{-1}) and K (₹310.45 kg ha^{-1}) uptake and was observed at par with rice-greengram+sunflower. The lowest N, P, K uptake was found in rice – greengram sequence (Table 3). Lady's finger and sunflower are heavy feeder of nutrients, so inclusion of these two crops in the system resulted in more uptake of N, P, K than that of greengram crop. Moreover, greengram uptakes less amount of nutrients from the soil due to its low yield. This result is in inconformity with the findings of Upadhyay *et al.,* 2011, Yadav *et al.,* 2013 and Prasad *et al.,* 2013.

Maximum P uptake was found in Kakdwip block (₹51.44 kg ha^{-1}), which was slightly higher than that of Mandirbazar block. No significant difference for N and K uptake was observed between these two blocks.

Resource Use Efficiency: The highest land use efficiency (LUE) was observed in rice-lady's finger (79.32%), followed by rice-sunflower (74.47%) and rice-greengram+sunflower (74.47%) and found statistically at par. The lowest LUE was recorded in rice-greengram system (69.13%) (Table 4). As rice is the common *kharif* crop in all the systems, the LUE is governed by the duration of summer crops. Among the summer crops lady's finger remained in the field for longer duration than any other crops, followed by sunflower and greengram. The highest irrigation water use was recorded in rice-lady's finger sequence (13.47 cm), then in rice-sunflower (10.83 cm), rice-greengram+sunflower (9.48 cm) and rice-greengram (4.11 cm) (Table 4). The highest irrigation water use in rice-lady's finger system was mainly due to longer duration of lady's finger crop as well as higher amount of irrigation water requirement. Irrigation water use efficiency is one of the most important factors to be considered for choosing suitable cropping system in

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Table 3. Effect of different cropping sequence on economics and nutrient uptake

Treatment	Cost of production ('000 ₹ha^{-1})	Net return ('000 ₹ha^{-1})	B:C ratio	Nutrient uptake (kg ha^{-1})		
				N	P_2O_5	K_2O
Block 1	70.88	49.06	1.64	309.157	47.81	266.37
Block 2	70.78	75.01	1.91	306.491	51.44	267.52
SEm (±)	-	0.94	0.01	8.255	1.26	6.12
CD(0.05)	-	2.61	0.03	NS	3.48	NS
Cropping System						
R-G	53.12	28.91	1.55	269.21	36.40	206.88
R-S	59.44	40.36	1.70	320.89	66.62	310.45
R-S+G	56.28	34.28	1.62	316.28	53.76	295.37
R-L	117.78	144.60	2.24	324.93	41.73	255.07
SEm (±)	-	1.33	0.01	11.67	1.78	8.65
CD (0.05)	-	3.68	0.04	32.36	4.92	23.97

R-G: Rice-Greengram, R-S: Rice-Sunflower, R-S+G: Rice-Sunflower+Greengrm (2:4), R-L: Rice-Lady's finger

Table 4. Resource use efficiency (pooled over two years)

Treatments	Land use efficiency (LUE) (%)	Economic efficiency (₹ha^{-1}day^{-1})	Irrigation (cm)	Irrigation water use efficiency (kg ha-cm^{-1})	Employment generation (Man days ha^{-1})	Energy output ('000MJ/ha)
Block 1	71.48	134.42	10.84	1222.86	352	174.62
Block 2	77.53	205.52	8.10	2546.58	351	174.67
SEm (±)	-	-	-	-	-	0.45
CD(0.05)	-	-	-	-	-	NS
Cropping System						
R-G	69.13	79.22	4.11	3159.60	303	159.35
R-S	74.47	110.58	10.83	1081.24	320	179.79
R-S+G	74.47	93.93	9.48	1078.36	311	175.18
R-L	79.32	396.15	13.47	2219.69	475	184.26
SEm (±)	-	-	-	-	-	0.63
CD (0.05)	-	-	-	-	-	1.75

R-G: Rice-Greengram, R-S: Rice-Sunflower, R-S+G: Rice-Sunflower+Greengrm (2:4), R-L: Rice-Lady's finger

irrigation water scared area like coastal saline flood plain of West Bengal. It is directly related to the yield of component crops and inversely related to the amount of irrigation water used for growing crops. Rice crop was grown fully under rainfed condition, so yield of summer crops and amount of water used for raising those crops made difference among the cropping systems. Maximum irrigation water efficiency was observed with rice-greengram system (₹3159.60 kg ha-cm^{-1}), followed by rice-lady's finger system (₹2219.69 kg ha-cm^{-1}) and rice-sunflower (₹1081.24 kg ha-cm^{-1}). The lowest water productivity was recorded in rice-greengram+sunflower (₹1078.64 kg ha-cm^{-1}) system. Among the two blocks better irrigation water use efficiency was recorded in second block (₹2546.58 kg ha-cm^{-1}) (Table 4). The highest irrigation water use efficiency was observed in rice-greengram sequence due to very negligible irrigation water was utilized for successful growing of the crops.

Though the requirement of irrigation for lady's finger was the highest among all summer crops but the second highest water productivity of a system containing lady's finger was mainly due to significant higher yield of lady's finger than other crops. Chitale *et al.*, (2011) also reported that higher irrigation water use efficiency with rice-brinjal-green manuring and rice-onion-green manuring. Higher irrigation water efficiency was observed in second block due to higher REY and less irrigation water application. Employment generation was also found highest in rice-lady's finger system (₹475 man days ha^{-1}) due to more involvement of labour in harvesting, irrigation and management of lady's finger. The lowest employment generation was found with rice-greengram system (303 man days ha^{-1}) as greengram required less labour than other crops. Economic efficiency

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refers to per day net return of a cropping system. The rice-lady's finger had the highest economic efficiency (396.15 ha^{-1} day^{-1}), followed by rice-sunflower system (110.58 ha^{-1} day^{-1}), rice-greengram+sunflower (93.93 ha^{-1} day^{-1}) and rice-greengram (79.22 ha^{-1} day^{-1}). Like other resources the higher economic efficiency was found in second block (Table 4).

Energetics: The highest energy output was found in rice-lady's finger system (1,84,260 MJ ha^{-1}), followed by rice-sunflower (1,79,790 MJ/ha), rice-greengram + sunflower (1,75,180 MJ/ha) against lowest value of 1,59,350 MJ ha^{-1} found with rice-greengram sequence (Table 4). This is because of lower productivity of greengram crop as compared to other summer crops. Regarding energy output no significant difference was recorded between the two blocks (Table 4). Mishra *et al.,* (2013) also reported higher output energy with rice-vegetable cropping system.

Thus, rice-lady's finger is the most efficient, resource conservative, highly profitable cropping system under coastal flood plain, which has the potential to serve as a viable and better alternative cropping system with limited irrigation facility to the existing rice-fallow and rice-greengram system. However, farmers still has the reservation to take this cropping system mainly due to its high cost of cultivation and labour crisis.

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Evaluation of Production Potential for Rice-Based Cropping Sequences on Cultivators' Fields in Sub-Tropical Low Hills Zone of Himachal Pradesh

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Abstract: Five rice-based cropping sequences *viz.* rice-wheat, rice-radish- potato, rice-potato-French bean, rice-potato-onion and rice-berseem + oats were evaluated on cultivators' fields for their production potential and economic feasibility in the low hills of Una and Kangra districts of Himachal Pradesh. Five year's (2007-08 to 2011-12) results revealed that rice-potato-onion, cropping sequence recorded significantly higher rice equivalent yield (14705 kg ha^{-1}) and net return (Rs 149597 Rs ha^{-1}), which was at par with rice-potato - French bean (12858 kg ha^{-1} and 117761 Rs ha^{-1}, respectively) and rice-radish-potato (11701 kg ha^{-1} and 109548 Rs ha^{-1}, respectively) cropping sequence. The extent of rice equivalent yield and net returns increase under rice-potato-onion, rice-potato-French bean and rice – radish – potato sequences was 177.8 & 102.0, 142.9 & 59.0 and 121.0 & 47.9%, respectively, over the conventional rice-wheat cropping sequence. In terms of total calories, only rice - potato - onion and rice-radish-potato cropping sequences could excel over the rice-wheat sequence. Total calories in rice-berseem+oats sequence were 81.4% of that realized under the rice-wheat cropping sequence. Conventional rice – wheat cropping system was superior over all the tried cropping systems in terms of physical energy intensity as well as economic energy intensity terms. Land use efficiency ranged between 76.5 to 97.9 % under different cropping systems.

Key Words: Cropping Sequences, Economics, Production Efficiency, Rice

Rice-wheat is the most important cropping system in India (Prasad, 2005). It occupies 10.5 m ha productive lands in Indo-Gangetic plains and contributes about 25% of the national food production. This system has sustained over the years and brings together conflicting and complementary practices. Because of high productivity, stability, low risk, and assured marketing the wide adoption of this system will also play a major role in future planning to sustain self sufficiency of food grains (Singh *et al*., 2012). But now the productivity of both the crops has stagnated and factor productivity is declining year after year. In Himachal Pradesh, this system covers more than 80 thousand hectares with average productivity of 3.07 t ha^{-1} (Anonymous, 2013) as against the national average of 5.70 t ha^{-1}. The farmers realize much of their food security from this cropping system and the low production level need immediate attention for the efforts to be geared in strengthening it. Besides food security, the low production levels jeopardize farmers' economic security to a considerable extent. To strengthen the economic security, it is imperative to intensify and diversify the existing rice-wheat system. Therefore, it is essential to diversify the system with rice as the base crop with more productive and profitable crops in place of wheat on cultivators' fields on participatory mode.

MATERIAL AND METHOD

Field investigation to evaluate the production potential of rice- based cropping sequences was taken under the On-Farm Research Programme of 'All India Coordinated Research Project on Integrated Farming Systems', Project Directorate of Farming System Research, Modipuram (ICAR) for five years (2007-08 to 2011-12).

During the years 2007-08 to 2008-09 experimental trials were conducted at 3 centres viz; Nandpur and Kalruhi in district Una and Khabli in district Kangra, whereas during the subsequent three years (2009-10 to 2011-12) trials were conducted within at four centres viz; Jawali, Rehan Tripal and Fatehpur in district Kangra. During 2009-10,there were three centres (excluding Fatehpur) with four locations per centre, whereas during subsequent years, trials were conducted at all the four centres with three locations per centre.

Five rice-based cropping sequences *viz.* rice-wheat, rice-radish-potato, rice-potato-French bean, rice-potato-onion and rice-berseem + oats were evaluated at farmers' fields. The crops in each cropping sequence were raised in accordance with the recommended package of practices (Table 1).

The soils of the zone were inceptisols, texture varying from loamy sand to silty clay loam, with pH 5.6-8.2.

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Table 1. Varieties, fertilizer dose (kg/ha), sowing and harvesting time of different crops

Crop	Variety	Fertilizer dose (kg/ha)			Sowing Time	Harvesting Time
		N	P_2O_5	K_2O		
Rice	Kasturi / HPR 1068	90	40	40	16 May - 3 June	9-30 Oct.
Wheat	HPW-184/ HPW 236	120	60	30	2-19 Nov.	10-30 April
Radish	Japanese white	100	50	40	15 Oct. - 5 Nov.	15 Jan. - 15 Feb.
Potato (spring)	Kufri Jyoti	120	80	60	21 Jan. - 19 Feb.	29 April - 28 May
Potato (autumn)	Pukhraj	120	80	60	8 Oct. - 6 Nov.	9 Jan. - 13 Feb.
French bean	Contender	50	80	60	5 Feb. - 1 April	26 April - 10 June
Onion	N-53/ AFDR	125	75	60	25 Dec. - 10 Jan.	25 April - 15 May
Berseem + oats	Local	25	60	-	25 Oct. - 14 Nov.	18 April - 12 June

Organic carbon was in the range of low to high in both the farming situations. It ranged from 0.3 to 0.85% in FS I (Farming situation I, Una & Kangra) and from 0.31 to 0.91% in FS II (Farming situation II, Kangra) with mean of 0.53 and 0.59%, respectively. Available N content was low to medium in both the farming situations ranging from 128.0 - 273.1 kg/ha in FSI and from 199.3 -337.9 kg/ha in FSII. Available P was medium to very high in FS I (13- 63.3 kg/ha) and low to very high in FS II (6.0 - 65.7 kg/ha). Available K content was low to high in both FS I (107.2-425.6 kg/ha) and FS II (60.8-399.2 kg/ha) (Table 2). The variation in the content of available P and K as determined in terms of coefficient of variation (CV %), was large in both the farming situations followed by OC, N and pH. The average annual precipitation recorded was 795 mm, 1479 mm, 1141 mm, 1841 mm and 1623 mm during 2007-08, 08-09, 09-10, 10-11 and 2011-12, respectively, whereas, mean maximum and minimum temperature of the test sites varied from 27.2 to 29.1 °C and 14.3 to 16.9 °C, respectively throughout the period of study.

Economics of the crop sequences was computed, based upon the farm gate prices. Area equivalent ratio (AER), relative profit, additional profit and profit equivalent ratio (PER) were determined according to studies conducted by Rana *et al.* (2010) i.e.,

AER = Cost of cultivation of conventional cropping sequence divided by cost of cultivation of alternative cropping sequence

Relative profit (Rs ha^{-1}) = AER multiplied by net returns (Rs ha^{-1})

Additional profit (Rs ha^{-1}) = Relative profit of alternative cropping sequence minus net returns of conventional cropping sequence

PER = Relative profit (Rs ha^{-1}) divided by net returns of conventional cropping sequence

Land utilization efficiency was worked out by summation of duration of each crop under individual crop sequence divided by 365. System productivity (kg $ha^{-1}day^{-1}$) was obtained by dividing total production in terms of rice equivalent in a sequence by the total duration of year (365), while system profitability (Rs $ha^{-1}day^{-1}$) was obtained by dividing net monetary return by 365. Energy intensity was worked out as follow. Energy intensity (physical terms) = energy output/equivalent yield, Energy intensity (economic terms) = energy output/cost of cultivation.

For comparison among crop sequences, the economic yield of crops were converted into rice equivalent on price basis. Homogeneity of error variances was tested by using Bartlett x^2– test; which were found to be homogeneous. Therefore, the data were pooled and analyzed in randomized block design.

RESULTS AND DISCUSSION

Crop yields: During the experimental period, the yields of rice, wheat, radish, onion, potato, French bean, and berseem + oats ranged between 2684-3274, 3498-3828, 13579-18643, 11253-17350, 8542-19774, 4554-8018 and 40702-54415 kg ha^{-1}, respectively (Table 4). Mean yield of rice, wheat, autumn potato and spring potato was, 97.4, 100.0, 5.9, and 18% higher than the average yield (rice 1550 kg,wheat 1530 kg & potato 14000 kg ha^{-1}) of these crops in Himachal Pradesh, respectively (Anonymous, 2013 and Baba, 2007). The mean yield of onion, radish and French bean was lower by about 13.2, 15.2 and 35%, respectively

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Table 2. Soil fertility status of the farmers' fields before sowing of the crops

Centre	pH	OC (%)	Available nutrients (kg ha^{-1})		
			N	P	K
Farming Situation I (Una & Kangra)					
(2007-08)					
Nandpur	8.0	0.85	273.1	48.5	298.7
Kalruhi	7.5	0.30	128.0	25.4	171.7
Khabli	7.2	0.49	217.6	13.0	130.7
(2008-09)					
Nandpur	8.2	0.66	236.0	57.3	161.7
Kalruhi	7.7	0.32	165.6	42.7	107.2
Khabli	7.7	0.58	144.9	63.3	425.6
Farming Situation II (Kangra)					
(2009-10)					
Jawali	6.0	0.50	238.3	24.2	159.6
Rehan	5.8	0.67	284.2	46.3	240.1
Tripal	5.8	0.31	199.3	6.0	60.8
2010-11					
Jawali	7.0	0.91	250.9	65.7	399.2
Rehan	5.9	0.60	284.3	28.4	248.6
Tripal	6.3	0.53	213.2	31.4	146.7
Fatehpur	5.8	0.57	271.8	25.4	297.6
2011-12					
Jawali	6.9	0.69	316.9	30.1	205.1
Rehan	5.6	0.68	337.9	23.4	173.2
Tripal	6.0	0.44	209.1	11.9	70.0
Fatehpur	5.6	0.61	323.2	21.4	165.4

than the state average yield (onion 175 qt, radish 225 qt and French bean 87 qt ha^{-1}) of these crops indicating their comparatively less productive after rice. This may probably be owing to disturbance in the structure of soil after pudding and its after effects. Yearly variations in crop yields were small during the study period. The CV values were < 10% for rice and wheat and about 10-20% for radish, onion and berseem + oats. The yearly variation in yield indicated by CV was 20-25% for rest of the crops.

Rice equivalent yields: Rice equivalent yield of the newly introduced cropping sequences viz. rice-potato-onion, rice-potato-French bean and rice-radish-potato was superior to prevalent rice - wheat sequence. However, rice-potato-onion cropping sequence was significantly superior in terms of rice equivalent yield (14705 kg ha^{-1}). The second best cropping sequence was rice-potato-French bean (12858 kg ha^{-1}) followed by rice-radish-potato (11701 kg ha^{-1}). The higher rice equivalent yield in these cropping systems was owing to replacement of wheat with high volume/high priced vegetable crops like potato, onion and French bean. Results are in conformity with number of findings suggesting inclusion of oilseeds, vegetables, ornamental or fodder crops to diversify the existing rice-wheat system for achieving higher rice equivalent yield (Kumar *et al.*, 2008; Sharma *et al.*, 2008; Tripathi and Singh, 2008). The rice-berseem + oats cropping sequence was also superior to rice-wheat in terms of rice equivalent yield. Rice-potato-onion, rice-potato-French bean and rice-radish-potato cropping sequences resulted in 177.8, 142.9 and 121.0%, higher rice equivalent yield, respectively, over the rice-wheat cropping sequence (Table 3).

Total calories of the main product: Rice - potato-onion, rice-radish-potato and rice-potato-French bean cropping sequences had excelled over the rice-wheat sequence in terms of production of total calories of the main product. Total calories under these cropping systems were higher about 26.4, 18.7 and 10.3%, respectively, than under the rice-wheat system. This indicated that these systems had high value of quality produce. Sharma *et al.* (2008) also documented higher energy output of cropping sequences in which, potato crop was included. In spite of significant increase in rice equivalent yield, total calories under rice-berseem + oats sequence were 75.7% of that realized under rice - wheat cropping sequence. It is pertinent to mention that

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Table 3. Crop yield, rice equivalent yield and return under rice based cropping sequences

Sequence	Yield (kg ha^{-1})			Rice equivalent (kg ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})
	Kharif	*Rabi* I	*Rabi* II			
FSI (average of 9 locations/replications) (2007-08)						
Rice-wheat	3114	3828	-	5666	100801	70236
Rice-Radish-Potato	3084	18643	17307	12004	185239	104870
Rice-Potato-French bean	3178	14092	7845	11590	182275	93565
Rice-Potato-Onion	3198	14591	16973	13232	203815	116064
Rice-Berseem + Oats	3199	47222	-	6977	110012	80048
LSD (P=0.05)				1009	15055	15055
FSI (average of 9 locations/replications) (2008-09)						
Rice-wheat	3070	3791	-	5597	100226	69661
Rice-Radish-Potato	3139	15474	19774	12166	187667	107298
Rice-Potato-French bean	3186	17566	7565	12491	194959	106249
Rice-Potato-Onion	3218	17391	17350	14219	218636	130885
Rice-Berseem + Oats	3221	54415	-	7574	119033	89069
LSD (P=0.05)				1135	16571	16571
FSII (average of 12 locations/replications) (2009-10)						
Rice-wheat	3177	3751	-	5261	115833	78877
Rice-Radish-Potato	3203	13579	15015	12814	237053	146570
Rice-Potato-French bean	3230	14658	8018	13385	253880	155511
Rice-Potato-Onion	3274	14306	13771	14958	275494	176684
Rice-Berseem + Oats	3261	47880	-	7251	137546	100932
LSD (P=0.05)				1358	24567	24567
FSII (average of 12 locations/replications) (2010-11)						
Rice-wheat	2684	3786	-	4577	112413	75457
Rice-Radish-Potato	2805	15411	9837	8560	178125	87642
Rice-Potato-French bean	2828	8542	4554	9233	171110	72741
Rice-Potato-Onion	2789	8542	11253	11405	235020	136210
Rice-Berseem + Oats	2823	50824	-	6635	139172	102558
LSD (P=0.05)				801	15589	15589
FSII (average of 12 locations/replications) (2011-12)						
Rice-wheat	2805	3498	-	5538	117102	74002
Rice-Radish-Potato	2831	14215	14328	13155	203129	99629
Rice-Potato-French bean	2795	13544	5273	17183	260162	151812
Rice-Potato-Onion	2864	13114	13501	19222	283781	175081
Rice-Berseem + Oats	3011	40702	-	8724	138402	90777
LSD (P=0.05)				2193	23635	22366
(Average of 54 locations/replications) (Pooled 2007-08 to 2011-12)						
Rice-wheat	2956	3722	-	5294	110249	74058
Rice-Radish-Potato	3001	15287	14887	11701	199553	109548
Rice-Potato-French bean	3028	13442	6534	12858	215128	117761
Rice-Potato-Onion	3053	13322	14282	14705	246919	149597
Rice-Berseem + Oats	3091	40048	-	7450	130423	93579
LSD (P=0.05)				1324	19447	19165

Rice (Basmati) Rs 15.0-18.0 kg^{-1}; Wheat Rs 10.0-11.0 kg^{-1}; Onion Rs 5.00-10.00 kg^{-1}; Potato Rs 4.50-7.00 kg^{-1}; French bean Rs 8.00-20.00 kg^{-1}; Berseem + Oats (green fodder) Rs 1.20-1.50 kg^{-1}

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in spite of higher total energy output of the main product; all the new cropping systems were inferior to the conventional rice – wheat cropping system in terms of energy intensity both in physical as well as economic terms (Table 4). It is therefore, evident that the system has not to be given up completely.

Economics: Rice -potato - onion sequence fetched higher net returns (Rs 149597 ha^{-1}) than other cropping sequences (Table 4), which was followed by rice-potato-French bean rice-radish-potato and rice-berseem+oats sequences. The increase in net profit might be due to higher yields of crops under crop sequences. Chaudhary *et al* (2001) have also reported higher net income by diversification of the existing rice-wheat cropping system. Rice-potato-onion, rice-potato-French bean, rice-radish-potato and rice-berseem+oats cropping sequences, resulted in 102.0, 59.0, 47.9 and 26.4% higher net returns, respectively, over the rice - wheat cropping sequence. Rice - berseem + oats registered higher B: C ratio than other cropping sequences. In spite of higher yields and net returns, rice - potato – onion, rice - potato - French bean and rice-radish-potato resulted in lower B: C ratio than rice-wheat cropping sequence due to higher cost of cultivation of potato and onion.

Land use efficiency: The land use efficiency ranged between 76.5 to 97.9% under different cropping systems (Table 5). All the new cropping sequences occupied the land for longer period of time and thus registered higher land utilization indices than rice-wheat cropping sequence. Rice-potato-onion registered highest land utilization efficiency (97.9%) followed by rice- berseem + oat (84.0 %) and rice- potato- French bean cropping sequence (82.4%). The field remained idle for about three months under rice-wheat cropping sequence. From the LUE of rice- wheat crop sequence, there was possibility to include some other short duration crop to maximize returns.

Production efficiency: As the indication of AER (0.372-0.402), a farmer cultivating 'rice-wheat' in one ha with cultivation cost of Rs 36191, when switches to alternative rice-vegetable-vegetable cropping sequence ('rice-potato-onion', 'rice-radish-potato' and 'rice-potato-French bean') can cultivate 37-40% of the area with the same amount (Table 7). Consequently relative profit from these alternative cropping sequences is also reduced to 37-40% of that obtained from one ha .

This was 59% under 'rice-radish-potato' and 'rice-potato-French bean', and 75% under rice-potato-onion of what was under rice-wheat. The further analysis indicated that to obtain the same return as under 'rice-wheat', the new cropping systems viz 'rice-potato-onion', 'rice-radish-potato', 'rice-potato-French bean' and rice-berseem+oats have to be sown in 49.5, 67.5, 62.9 and 79.1% of the entire area. By switching to cultivation of these alternative copping systems ('rice-potato-onion', 'rice-radish-potato' and 'rice-potato-French bean'), to get equivalent return as under one ha rice-wheat, a farmer would require Rs 12004, 24638, and 25092 more. However, the farmer can spare 20-50% of his land resource for some other economic activity.

Table 4. Total calories of the main product and energy intensity under different cropping systems

Cropping sequence	Total calories (10^6 K cal ha^{-1})				Energy intensity	
	Kharif	*Rabi* I	*Rabi* II	Total	Physical terms (k cal ha^{-1})	Economics (k cal ha^{-1})
Rice-wheat	10.1	12.9		23.0	4348.1	636.0
Rice-radish-potato	10.3	2.6	14.4	27.3	2335.9	303.7
Rice-potato-French bean	10.4	13.0	2.0	25.4	1974.2	260.7
Rice-potato-onion	10.5	12.9	5.7	29.1	1979.4	299.1
Rice-berseem+oats	10.6	8.1		18.7	2516.7	508.9
LSD				1.1		

Table 5. Duration and land use efficiency under different cropping systems

Treatment	Duration (days)				LUE (%)
	Kharif	*Rabi* I	*Rabi* II	Total	
Rice-wheat	119.7	159.5		279.2	76.5
Rice-radish-potato	119.7	80.8	91.7	292.2	80.0
Rice-potato-French bean	119.7	89.8	91.3	300.8	82.4
Rice-potato-onion	119.7	89.5	148.0	357.2	97.9
Rice-berseem+oats	119.7	187.0		306.7	84.0

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Table 6. Economics, productivity and profitability of different crop sequences

Treatment	B:C ratio	COC System (Rs. ha^{-1})	AER	Relative profit (Rs)	Additional profit	PER	Productivity (Kg ha^{-1}day^{-1})	Profitability (Rs. ha^{-1}day^{-1})
Rice-wheat	2.05	36191	-				14.5	202.9
Rice-radish-potato	1.22	90004	0.402	44050	-30008	0.595	32.1	300.1
Rice-potato-French bean	1.21	97367	0.372	43771	-30286	0.591	35.2	322.6
Rice-potato-onion	1.54	97321	0.372	55631	-18427	0.751	40.3	409.9
Rice-berseem+oats	2.54	36844	0.982	91920	17862	1.241	20.4	256.4
LSD		282					3.6	25.5

All the cropping sequences resulted in higher production efficiency in terms of system productivity (kg ha^{-1}day^{-1}) and system profitability (Rs ha^{-1}day^{-1}) over the rice-wheat cropping sequence. Rice-potato-onion cropping sequence recorded the highest system productivity (40.3 kg ha^{-1}day^{-1}) and system profitability (Rs 409.9 ha^{-1} day^{-1}) than the other cropping sequences, which was followed by rice-potato-French bean and rice-radish-potato cropping sequences (Table 6). System productivity (kg ha^{-1} day^{-1}) under rice-potato-onion, rice-potato-French bean and rice-radish-potato was, 2.8, 2.4 and 2.2, times higher than conventional rice-wheat cropping system. These crop sequences were also higher in case profitability by 2.0, 1.6 and 1.5 times, respectively, over the rice-wheat system. The system productivity and system profitability scenario clearly depicted that there is sufficient availability of food and cash for an average marginal family having one ha of land.

It is concluded that farmers of low hills of HP can adopt rice-potato-onion, rice-potato-French bean and rice-radish-potato cropping sequences for higher net income as an alternative to rice-wheat cropping system. However, complete replacement is not advisable.

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Effect of Cropping Systems on Crop Productivity and Profitability Under South Gujarat Condition

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Abstract: A field experiment was carried out during 2009-10 to 2011-12 at Farming System Research Farm, Navsari Agricultural University, Navsari (Gujarat) to study the effects of cropping systems on crop productivity and profitability in south Gujarat regjon. Compared to minimum tillage, paddy equivalent yield (PEY) and net profit under conventional tillage were 5.9 and 9.9 % higher, respectively. In pooled result, paddy-sorghum – summer green gram (159.33 q ha^{-1}) recorded significantly higher PEY, which was at par with paddy –green manuring -summer groundnut (142.01 q ha^{-1}). Paddy - sorghum – summer green gram recorded significantly higher net profit of ₹117669 ha^{-1}, which was at par with paddy –green manuring -summer groundnut (₹94163 ha^{-1}). Mulch has no significant effect on paddy equivalent yield during individual years but in pooled result, mulching with crop residue recorded significantly highest PEY (135.15 q ha^{-1}) and net profit (₹140342 ha^{-1}) over no mulch treatment. Significant effect of 25 % higher RDF on PEY (138.55 q ha^{-1}) and net profit ₹93144 ha^{-1} over RDF was observed during all individual years and in pooled result.

Key Words: Cropping System, Mulch, Paddy Equivalent Yield, Profitability, Productivity

Soil organic matter (SOM) is a useful indicator of soil quality since it determines the fertility, productivity and sustainability in agricultural systems where nutrient poor and highly weathered soils are managed with little external input (Feller and Beare, 1997). The dynamics of SOM are influenced by practices such as tillage, mulching, removal of crop residues and application of organic and mineral fertilizers. Removal of crop residue from the fields is known to hasten soil organic carbon (SOC) decline especially when coupled with conventional tillage. This is a common practice in most smallholder farms. Carbon sequestration in agricultural soils can be enhanced by addition of carbon inputs from crop residues. Locally available organic nutrient sources are often used in the form of farmyard manure, crop residues and green manure.

Tillage plays an important role in the nutrient storage and release from SOM, with conventional tillage (CT) soil disturbance through tillage is a major cause of reduction in the number and stability of soil aggregates and subsequently organic matter depletion (Six *et al.*, 2000). Cropping systems play an important role in determining soil physical characteristics and in nutrient cycling mechanisms. Present investigation was undertaken to assess the effects of conventional tillage, crop residue and cropping systems on yields between different cropping systems.

MATERIAL AND METHODS

An experiment was initiated during 2009-12 at Farming System Research Farm, Navsari Agricultural University, Navsari (Gujarat) to study the effects of cropping systems on crop productivity and profitability under heavy rainfall zone of south Gujarat condition. Climate is characterized by fairly hot summer, moderately cold winter, humid and warm monsoon with heavy rain. Average rainfall during the experimental years recorded about 1600 mm in 62 rainy days with highest evaporation rate of 7.2 (mm/day) in the month of May. Minimum bright sunshine hours observed during month of July (1.2 BSSH), while clear atmosphere with maximum bright sunshine hours in the month of April (11.0 BSSH). The soil of the experimental site was clayey with 0.59 % organic carbon, 1.46 g cc^{-1} bulk density, 256 kg/ha available nitrogen, 21.4 kg ha^{-1} available phosphorus and 260 kg ha^{-1} available potassium. The experiment was conducted in split-split plot design with three replications. There were two tillage practices as main plots, T_1: Minimum tillage, T_2: Conventional tillage (Puddling). Three cropping systems i.e., C_1: Paddy-green manuring-summer Groundnut, C_2: Paddy-*rabi* castor-green manuring, C_3: Paddy-sorghum-summer green gram, the two levels of mulch i.e., M_1: No mulch and M_2: Mulch with wheat reside incorporation. The recommended dose of fertilizers were 100-30-0,120-25-0, 80-40-0, 25-50-0 and 20-40-0 (NPK kg ha^{-1}) for paddy, castor, sorghum, groundnut and green gram, respectively. There were two levels of fertilizer F_1: RDF, F_2: 25% of RDF (recommended dose of fertilizer). Paddy equivalent yield (PET) was

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calculated on the basis of farm gate prices for each crop. no sever pests and diseases were found during the crop seasons.

RESULTS AND DISCUSSION

Tillage: The results revealed that tillage had not effect in respect of paddy equivalent yield, gross profit and net profit of sequences during individual years but showed significant effect on pooling the data. Conventional tillage recorded significantly highest paddy equivalent yield (136.01 q ha^{-1}) to the tune of 5.9 % over minimum tillage (128.01 q ha^{-1}). Same trend was observed in case of gross return and net profit. Increase in net profit of conventional tillage (₹91918 ha^{-1}) over minimum tillage (₹83621 ha^{-1}) to the tune of 9.9 % (Table 1). Reduced mineralization of plant residues have often been considered responsible for the low yields obtained with minimum tillage systems. These results are similar to the findings of Małecka and Blecharczyk (2008).

Cropping systems: The perusal of data indicated that the effect of cropping systems during individual year was significant among the treatments. Significantly highest paddy equivalent yield (135.98 q ha^{-1}) was recorded under C_3 during 2009-10 and 2011-12, while in 2010-11, C_3 was as par with C_1 (129.39 q ha^{-1}). In pooled data, C_3 (159.33 q ha^{-1}) recorded significantly higher PEY, which was at par with C_1 (142.01 q ha^{-1}). The cropping sequence paddy-*rabi* castor secured significantly lowest PEY (94.62 q/ha) over C_1 and C_3 (Table 1).

In case of net profit, C_3 recorded significantly highest net profit during individual years. In pooled data cropping system C_3 recorded significantly higher net profit of ₹117669 ha^{-1}, which was at par with C_1 (₹94163 ha^{-1}) due to higher land use efficiency of this cropping sequence. Cropping system C_2 recorded significantly lowest net profit over C_1 and C_3. (Table 1)

Mulch: Mulch has no significant effect on paddy equivalent yield during initial years 2009-10 and 2010-11; while residue incorporation recorded significantly highest PEY (139.58 q ha^{-1}) over no mulch during 2011-12. In pooled data, mulching (135.15 q ha^{-1}) recorded significantly highest PEY over no mulch (Table 1), which will be due to gradual addition of large amount of easily decomposable mulch material. Gross and net profits were not affected due to use of mulch in experimentation, but in pooled results, mulching recorded significantly highest gross profit of ₹147118 ha^{-1} over no mulch (₹140342 ha^{-1}), but net profit ha^{-1} was not significant (Table 1). These results are in accordance with the findings of Jat *et al* (2012)

Fertilizer: PEY was significantly highest with additional fertilizer during 2009-10 (149.05 q ha^{-1}), 2010-11

Table 1. Effect of management of cropping systems for resource conservation on paddy equivalent yield and economics of crop sequence

Treatment		Paddy equivalent yield (q/ha)				Gross profit (Rs./ha)	Net profit (Rs./ha)
		2009-10	2010-11	2011-12	Pooled	Pooled	Pooled
A. Main plot:- Tillage x Cropping systems							
Tillage	T_1 : Minimum tillage	135.63	116.94	131.53	128.01	139402	83621
	T_2 : Conventional tillage	146.24	122.23	139.47	136.01	148117	91918
CD at 5 %		NS	NS	NS	57.77	6292	6292
Cropping systems	C_1 : Paddy –Summer Groundnut	153.47	129.39	143.19	142.01	154654	94163
	C_2 : Paddy – *Rabi* Castor	93.93	93.39	96.68	94.67	103092	51476
	C_3 : Paddy - Sorghum – Summer green gram	175.39	135.98	166.68	159.33	173533	117669
CD at 5 %		13.33	8.62	17.58	23.14	25196	25196
B. Sub Plot :- Mulch x Fertilizer							
Mulch	M_1 : No mulch	138.25	116.39	131.46	128.87	140342	85809
	M_2 : Mulch/Residue Incorporation	143.09	122.79	139.58	135.15	147178	89730
CD at 5 %		NS	NS	5.86	3.67	3993	NS
Fertilizer	F_1 : RDF	132.81	114.36	129.25	125.47	136639	82394
	F_2 : 25% higher of RDF	149.05	124.82	141.78	138.55	150881	93144
CD at 5 %		6.34	7.32	5.86	3.68	4011	4011

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Table 2. Effect of management of cropping systems for Resource Conservation on grain and straw yield of crop sequence

Treatment		Grain and Straw yield (q ha^{-1})															
		2009-10						2010-11						2011-12			
		Kharif		*Rabi*		Summer		*Kharif*		*Rabi*		Summer		*Kharif*		*Rabi*		Summer	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A. Main plot:- Tillage x Cropping systems																			
Tillage	T_1	39.3	40.1	16.6	16.6	10.8	38.2	25.9	41.2	17.1	18.2	8.9	35.5	30.7	60.4	17.3	62.2	8.3	33.4
	T_2	42.1	42.9	18.6	18.6	11.5	41.2	28.4	43.8	17.3	18.6	9.26	37.7	31.8	63.7	17.2	54.7	9.97	39.4
Cropping systems	C_1	40.1	40.6	0.0	0.0	20.3	52.9	25.5	38.6	0.0	0.0	18.5	48.9	29.3	60.4	0.0	0.0	19.8	54.2
	C_2	40.6	41.5	20.3	0.0	0.0	0.0	27.1	42.7	26.3	0.0	0.0	0.0	32.9	62.5	24.1	0.0	0.0	0.0
	C_3	41.4	42.4	32.5	32.5	13.2	66.2	28.9	46.1	25.3	55.1	8.6	60.8	31.8	63.3	27.6	63.7	7.7	54.9
B. Sub Plot :- Mulch x Fertilizer																			
Mulch	M_1	40.1	40.8	17.2	17.2	11.0	38.8	26.6	40.4	16.6	17.9	8.8	35.6	30.3	61.4	16.6	58.0	8.8	35.0
	M_2	41.2	42.2	0.0	17.9	11.3	40.4	27.7	44.5	17.7	18.8	9.2	37.5	32.1	63.6	17.8	58.81	9.4	37.7
Fertilizer	F_1	38.2	39.3	16.5	16.5	10.5	38.5	26.0	40.4	16.0	18.1	8.79	35.5	29.7	60.6	15.7	56.2	8.95	35.5
	F_2	43.2	43.7	18.7	19.7	11.8	41.0	28.3	44.6	18.3	18.6	9.3	37.6	32.7	63.5	18.7	60.6	9.3	37.2

Table 3. Soil fertility status at end of crop sequence after three years (2011-12)

Treatment		Available nutrients (kg ha^{-1})			Organic carbon (%)
		N	P	K	
A. Main plot:- Tillage x Cropping systems					
Tillage	T_1	264.67	23.97	155.94	0.587
	T_2	265.19	24.02	158.70	0.584
Cropping systems	C_1	264.93	22.12	158.36	0.583
	C_2	265.53	25.37	156.80	0.581
	C_3	264.35	24.50	156.80	0.592
B. Sub Plot :- Mulch x Fertilizer					
Mulch	M_1	263.11	23.50	155.94	0.573
	M_2	266.77	24.49	158.70	0.599
Fertilizer	F_1	261.54	23.00	156.63	0.576
	F_2	268.34	24.99	158.01	0.595
Initial status		256.00	21.40	160.00	0.590

(124.82 q ha^{-1}) and 2011-12 (141.78 q ha^{-1}) over recommended dose, while in pooled results, dose 125 % RDF recorded significantly highest PEY (138.55 q ha^{-1}) over recommended (125.47 q ha^{-1}) (Table 1). Similar findings were observed by Parvez *et al.* (2009).

Significant effect of 125 % RDF on net profit over RDF was observed during all individual years except 2010-11. Significantly highest net profit of ₹93144 ha^{-1} was recorded under enhanced over normal fertilizer (₹82394 ha^{-1}) in pooled data.

From the experimental results, it can be concluded that after three years, paddy- sorghum-green gram cropping system was beneficial for getting higher PEY, net profit by adopting conventional method with 25 % higher fertilizer recommended dose and crop residue mulch.

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Probability of Wet Spells, Expected Amount and Long-Term Trends of Rainfall for Crop Planning in Bihar

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Abstract: Rainfall analysis for Pusa, Purnia, Sabour and Patna representing North west alluvial plains (Zone I), North East alluvial plains (Zone II), and South Bihar alluvial plains (Zone III A and III B), respectively using annual and weekly rainfall data was carried out for Bihar state. The overall mean annual rainfall was lowest (1031 mm) for zone III B and highest (1466.7 mm) for zone II. But coefficient of variation was highest (30.8%) for Pusa (zone I) and lowest (23.7%) for Patna (zone III B). A long term significant decreasing trend in annual rainfall was observed in Patna (zone III B). At Pusa and Purnea, 25th to 34th SMW are favorable weeks for field preparation/sowing and transplanting of rice crop due to more than 75 per cent probability of rainfall of 10-30 mm. At Sabour, probability of rainfall more than 20 mm is 75 per cent during 25th-33rd week while for Patna; it is during 27th-34th SMW. So, sowing and field operations may be delayed by two weeks in Patna region. The study reveals that crops and varieties could be selected through the analysis of wet spell durations with the onset of monsoon in the given region. When monsoon is late or dry spell is encountered, practice direct seeded rice or intercropping of green gram or black gram. Under stress situations, less water requirement crops like sorghum, ragi, finger millet, etc. can be adopted in the region.

Key Words: Wet Spells, Rainfall Trend Analysis, Rainfall Probability, Crop Planning

Rainfall is the single most important factor in crop production planning in rainfed ecology. The information on annual, seasonal and weekly rainfall of a region is useful to design water harvesting structure for agricultural operations, field preparation, sowing, irrigation, fertilizer application and overall in field crop planning (Singh *et al*., 2008). Historically in Bihar, zone I and zone II are receiving too much rainfall to cause flood in the region, whereas, zone III B is characterized as rainfed region with low, erratic and uncertain rainfall pattern with frequent dry spells during the monsoon season. Hence monsoon cropping is tricky operation in the region as well as sudden crop failures during the *kharif* season is a common phenomenon due to early withdrawal of monsoon. Rainfall probability pattern has been studied by many scientists in India (Pradeep *et al*., 2012; Suchit *et al*., 2012) and concluded that rainfall occurrence is certain at greater than or equal to 80 per cent probability, while 50 per cent probability is the medium limit of certainty and may involve dry spell risk. Taking into account these climatic and probability factors, the study was conducted for four different locations situated in different agro-climatic zones of Bihar for interlinking the rainfall probability with the crop planning pattern in the region.

MATERIAL AND METHODS

Weekly rainfall data for the period 1955 to 2012 i.e. 58 years pertaining to Pusa (25° 98' N, 85° 13' E, 47 m msl), Purnea (25°98' N, 87°80' E, 37 m msl), Sabour (25° 23' N, 87° 70' E, 37 m msl) and Patna (25° 36' N, 85° 9' E, 58 m msl) representing North west alluvial plains (Zone I), North East alluvial plains (Zone II) and South Bihar alluvial plains (Zone III A and III B) of Bihar, respectively was used for analysis. Weekly, annual and seasonal rainfall distribution patterns were critically examined and analyzed. Trends were examined by Mann-Kendall rank statistics as described by Sneyers (1990). This test was used by several researchers to detect trends in hydrological time series data (Luo *et al*., 2008). An initial and conditional probability of weekly rainfall at different threshold limits (10, 20 and 30 mm) were computed using first order Markov chain process (Robertson, 1976). Expected amount of rainfall at a given probability level was computed for 24-39 SMW during monsoon season using Weibull's distribution (Chow, 1964).

RESULTS AND DISCUSSION

Variability in annual and seasonal rainfall: The average annual rainfall of Pusa (zone I) is 1246.9 mm with coefficient of variation (CV) of 30.8% (Table 1). About 83.8 per cent of annual rainfall is received from south west monsoon. The winter, pre monsoon and post monsoon season rainfall contribute 2.4, 7.9 and 5.9 per cent rainfall to the annual rainfall, respectively. For Purnea (zone II), the average annual rainfall is 1466.7 mm with CV 25.8 per cent. The contribution of monsoon, post monsoon, winter and pre monsoon season rainfall to the annual rainfall is 80.1, 6.5, 1.4 and 12 per cent, respectively. The average annual rainfall

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of Sabour (zone III A) is 1231.4 mm with CV of 24.5 per cent and monsoon season rainfall contribution is 78.7 per cent. The winter, pre monsoon and post monsoon rainfall contribution is 2.8, 10.4 and 8.1 per cent, respectively. The average annual rainfall of Patna (zone III B) is 1031.0 mm with CV of 23.7 per cent and monsoon season rainfall contribution is 85.9 per cent. The winter, pre monsoon and post monsoon rainfall contribution is 3.3, 4.5 and 6.3 per cent, respectively.

Trend analysis: The long-term annual rainfall of Patna (zone III B) shows significant decreasing trend (Table 1). In Pusa (zone I), it also shows decreasing trend but statistically non significant. In Purnea (zone II) and Sabour (zone III A), there is increasing trend but statistically not significant.

There is a decreasing trend of winter rainfall in all the zones though it is statistically not significant. There is significant increasing trend of pre monsoon rainfall in Patna (zone III B). In pre monsoon season, there is increasing trend of rainfall for all the zones except zone II, though it is statistically not significant. But there is decreasing trend of monsoon and post monsoon rainfall, in Pusa (zone I) and Patna (zone III B) though it is statistically not significant.

Initial and conditional rainfall probability analysis: An amount of 10 mm rainfall per week can be taken as the minimum requirement for seedbed preparation/sowing of rainfed *kharif* crops (Ahmed *et al.*, 2009). The long term rainfall data analysis revealed that at Pusa (zone I), initial {P (W)} and conditional {P (W/W) i.e. wet week followed by wet week} probabilities of getting 10 mm rainfall per week was 77-89 per cent from 25th to 34th standard meteorological week (SMW), in which, seed bed preparation/sowing can be done. Probability of receiving more than 20 mm rainfall per week was more than 75 per cent from 28th to 30th week and again during 32nd to 34th week, which would be an ideal time for transplanting or fertilizer application in the region. P (W/W) of getting 20 mm rainfall was 61-86 per cent from 25th to 33rd week and probability of getting 30 mm rainfall was 66-79 per cent during the same period (Fig. 1). In Purnea (zone II), probability of getting 10 mm rainfall per week was more than 80 per cent during 25th week and again from 28th to 30th SMW, which would be the ideal time for nursery bed preparation and again for transplanting of rice in 29th week. In 34th week rainfall pattern was again repeated, in which fertilizer application may be done. P (W/W) of getting 20 mm rainfall was 70-96 per cent during 25th-34th week and getting 30 mm rainfall was 59-93 per cent during the same period (Fig 1). Probability of 10 mm rainfall in Sabour region (zone III A) was 75-86 per cent during 25th to 33rd week, which would be ideal time for sowing and other cultural operations in the area (Fig 1). In Patna region (zone III B), from 25th to 34th week would be the ideal time of bed preparation/sowing of the crop due to probability of getting 10 mm rainfall was 70-88 per cent. Probability of getting 20 mm rainfall was 68-86 per cent from 27th to 34th week. P (W/W) of getting 20 mm rainfall was 70-91 per cent during 26th-34th week and of getting 30 mm rainfall was 64-84 per cent during the same period (Fig 1). Therefore these weeks are ideal for integrated field operations like sowing, fertilizer application etc. in these regions.

Expected rainfall amount and crop planning: As discussed above, rainfall at 75 per cent and 90 per cent probability is assured rainfall and at 50 per cent probability is the median limit for taking risk. At Pusa, the probability of

Table 1. Variation, percentage contribution (% C) and long term trends of seasonal and annual rainfall in four districts representing different zones of Bihar

Season	Pusa (zone I)				Purnia (zone II)			
	Rainfall (mm)	CV (%)	% C	Trend (mm/year)	Rainfall (mm)	CV (%)	% C	Trend (mm/year)
Annual	1246.9	30.8	-	-1.57	1466.7	25.8	-	0.81
Winter	30.3	75.8	2.4	-0.48	20.6	97.5	1.4	-0.10
Pre-monsoon	98.6	59.3	7.9	1.10	175.5	54.4	12.0	-0.14
Monsoon	1044.7	34.3	83.8	-1.20	1175.3	28.3	80.1	2.26
Post- monsoon	73.3	93.5	5.9	-0.99	95.4	99.0	6.5	-1.20
	Sabour (zone III A)				Patna (zone III B)			
Annual	1231.4	24.5	-	2.08	1031.0	23.7	-	-7.04*
Winter	34.8	89.3	2.8	-0.39	34.0	79.2	3.3	-0.51
Pre-monsoon	127.8	66.3	10.4	0.54	46.4	68.2	4.5	0.43*
Monsoon	969.7	25.0	78.7	2.39	886.1	25.1	85.9	-5.74
Post- monsoon	99.1	91.2	8.1	-0.46	64.5	94.5	6.3	-1.23

*Significant at 5 %

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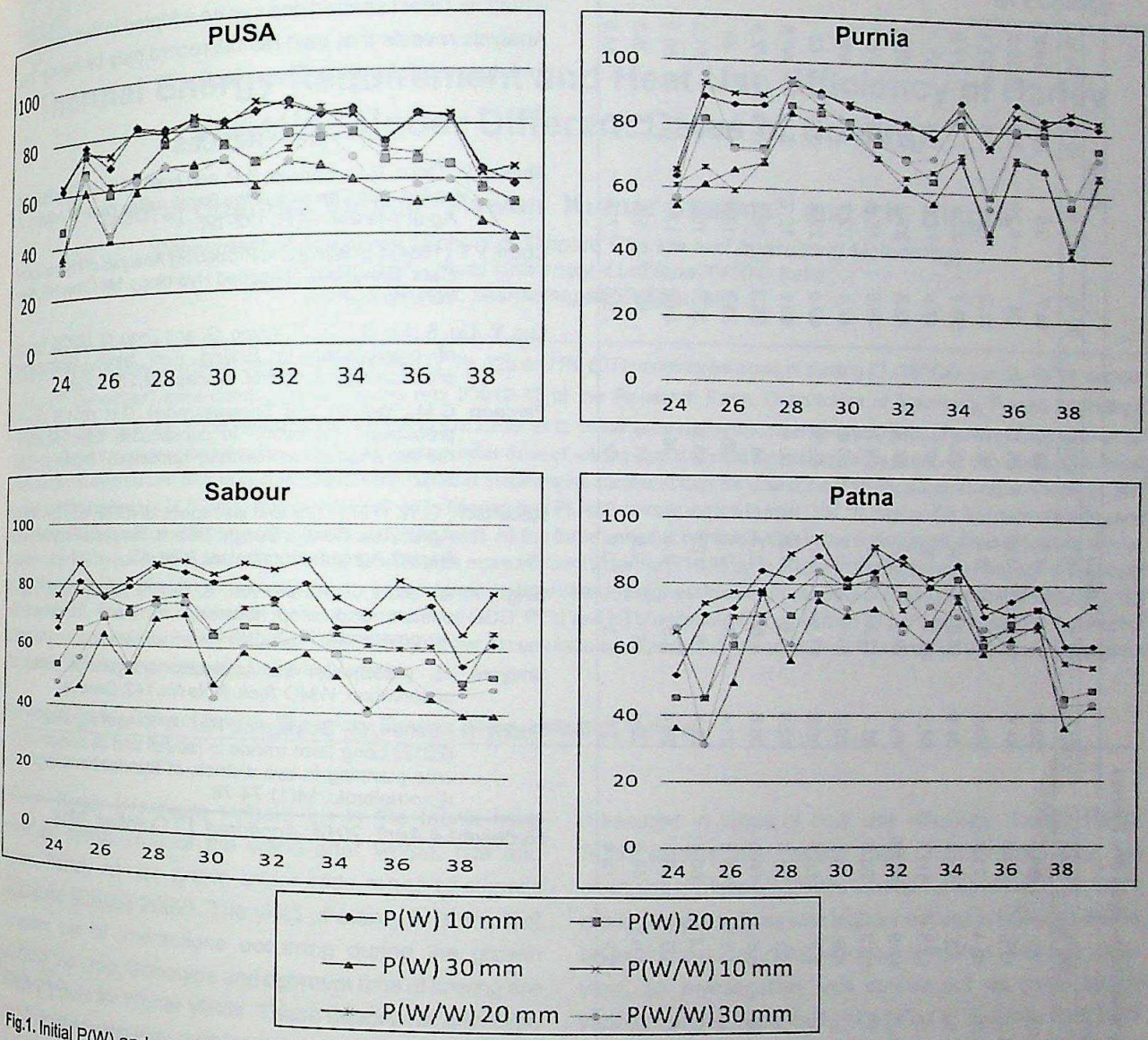

Fig.1. Initial P(W) and conditional probabilities P(W/W) of weekly rainfall at different threshold limit at Pusa, Purnia, Sabour & Patna

more than 30 mm rainfall from SMW 25th is above 50 per cent, but there is some risk. From 27th SMW, there is probability of more than 75 per cent of getting rainfall of more than 15 mm and farmers can initiate their field preparation operations and from 28th week expected rain becomes more than 20 mm, 27th and 28th week are an ideal time for sowing/transplanting of *kharif* crop and also for the crop fertilization based upon the rainfall pattern and intensity. In Purnea, the probability of more than 20 mm rainfall from SMW 25th is above 75 per cent and more than 10 mm rainfall is above 90 per cent (Table 2). From SMW 25th, sowing of kharif crop can be initiated in the region. In 28th and 29th week probability of receiving more than 30 mm rainfall is more than 75 per cent which is sufficient amount of rainfall for transplanting of rice in the region. In Sabour and Patna region, the probability of more than 10 mm rainfall is above 75 per cent from 25th and 26th SMW respectively. The probability of receiving more than 20 mm rainfall in the regions are from 28th and 29th week, respectively in which transplanting of rice can be completed.

Major crop of the region is rice, which is highly dependent on monsoon rainfall for nursery bed preparation, transplanting and maintenance of water in the field. Analysis indicates the need for selection of crops according to the probability of getting wet weeks preceded by wet weeks with the onset of southwest monsoon in the region. Timely monsoon will favour selection of long duration and high water requiring crops like rice. Late monsoon will lead to selection of crops with medium duration and moisture stress tolerant crops like ragi, finger millet and sorghum, in the moderate rainfall districts, where erratic monsoon behavior is observed. Pulses like green gram and black gram need to be selected often as intercropping based on varied rainfall

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Table 2. Expected weekly rainfall amount (mm) at different probability level (%) in Pusa and Purnea

SMW	Pusa				Purnea				Sabour				Patna			
	50 %	75 %	90%	Total	50 %	75 %	90 %	Total	50 %	75 %	90 %	Total	50 %	75 %	90 %	Total
24	18.4	5.4	1.2	32.3	32	9.6	2.2	56.5	22.6	7	1.7	38.4	14.7	3.6	0.6	29.6
25	34.4	10.8	2.7	58.9	47.5	24.2	11.6	59.5	31.5	12.8	4.6	45.1	24	8.2	2.3	38.3
26	32.0	9.3	2.1	57.4	53.8	24.8	10.4	71.6	39.9	16.8	6.2	56.2	31.2	10.3	2.8	51.2
27	42.9	16.1	5.1	65.2	52.8	21.8	7.9	75.4	34.9	12.8	4	53.6	50.3	20.8	7.6	71.8
28	56.2	22.6	7.9	81.8	85.4	41.3	18.5	111.1	54.2	22.3	8	77.7	47.6	17.6	5.5	73.1
29	50.9	20.3	7.1	74.2	82.6	39.8	17.8	107.5	45.8	19.1	7	64.9	72.3	33.4	14.1	96.5
30	46.5	19.8	7.5	65.0	50.6	25.7	12.2	63.6	33.1	12.5	4	49.7	49.5	18.2	5.6	76.2
31	42.2	17.8	6.6	59.3	53.5	23.0	8.8	74.5	40.4	16.1	5.6	58.8	47.1	22.5	9.9	61.3
32	49.7	21.0	7.8	70.0	37.7	17.3	7.2	50.1	35.9	13.1	4	55.3	49.6	22.8	9.6	66
33	47.5	19.1	6.7	69.0	42.1	14.4	4.1	67.8	42.9	15.6	4.8	66.4	40.6	15.7	5.2	60.5
34	47.2	19.1	6.8	68.3	45.2	20.9	8.8	60.0	26.8	8.8	2.3	44.1	55.3	26.2	11.4	72.5
35	33.3	12.6	4.0	50.0	34.9	13.0	4.1	53.3	23.4	7.8	2.1	38	33.7	13.8	5	48
36	38.8	16.0	5.8	55.3	48.1	24.1	11.3	60.8	25.4	8	2	43.2	36.9	15.8	6	51.3
37	39.4	15.4	5.2	58.2	51.2	22.6	9.0	69.9	23.4	8.5	2.6	36	44.6	17.7	6.1	65.2
38	23.8	8.1	2.2	38.1	29.8	11.5	3.8	43.9	20.4	5	0.9	41.4	16	5.5	1.5	25.3
39	26.1	6.5	1.2	51.9	46.7	17.0	5.2	72.4	24	5.3	0.8	52.1	25.6	7.7	1.8	44.9

situation. Direct seeded rice can be adopted in that situation. Analysis reveals that past rainfall record may be handy tool for future rainfall probability projections.

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Thermal Energy Requirement and Heat Use Efficiency of Barley Varieties Under Different Dates of Sowing

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Abstract: Field studies with three barley varieties (PL I72, PL 426 and PL 807) under three dates of sowing (D_1-16th October, D_2-15th November and D_3-15th December) were conducted during the rabi 20012-13 at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana to study the variation in the efficiency of varieties to utilise solar radiation under different dates of sowing. Crop sown on 16th October took more number of days from sowing to heading than other dates of sowing, thus it availed longest vegetative phase. All the varieties took almost same number of days for completion of emergence. Variety PL 807 availed more number of days for attainment of all phenological stages. Variety PL 807 consumed the highest (477 °C day) number of GDD up to tillering and PL 426 consumed the lowest (367 °C day) under first date of sowing and this differential behaviour of the varieties continued till harvest. All the three varieties behaved alike in the subsequent dates of sowing. Similar pattern was fallowed for PTU and HTU. Variety PL 426 was more efficient in terms of HUE up to 90 days of crop growth. Heat use efficiency of PL 807 for production of grain, straw and total dry matter (grain + straw) was the highest in all the three date of sowing and that of variety PL 426 was the lowest. The linear regression models indicated that GDD, PTU and HTU accounted for more than 97 per cent variation in the onset of different phenophases for barley varieties. Periodic dry matter accumulation and periodic HUE accounted for more than 94 per cent variation in the onset of different phenophases for barley varieties.

Key Words: Barley, Dates of Sowing, Phenology, Thermal Energy Utilization, Varieties

Barley (*Hordeum vulgare* L.) is the fourth most important cereal crop of the world after wheat, rice and maize. Barley can be grown under wide range of climatic conditions (Prasad 2002). The yield of a crop is a result of complex set of interactions occurring during the growth period of the crop. Genotype and optimum time of sowing are primary inputs for higher yields. These factors viz. genotype and date of sowing assumes importance in view of the photo and thermal requirements of the crop plant. Rates of most biological processes are affected markedly by temperature. Growth and development of any organism shows a significant response to temperature, which results from the integrated effect of temperature on many physiological processes involved (Reddy 2001). Plants require a specific amount of heat to complete their lifecycle i.e. from sowing to the maturity.

Barley is a long day plant. Every crop requires accumulation of a definite amount of heat energy to complete its life cycle. Growing degree days (GDD) are a simple means of relating plant growth, development and maturity to air temperature. The heat units or growing degree days concept assumes that the growth of plant is dependent on the total amount of heat to which it is subjected during its life cycle. Heat accumulated in terms of GDD in association with solar radiation determines the yield of a crop, which can be measured in terms of heat use efficiency (Nelson,1963). Such studies are gaining more importance under the changing climatic conditions as crop varieties and agronomic management options with higher heat use efficiency need to be explored under global warming scenarios. Keeping this in view, an investigation was carried out on three barley varieties under three dates of sowing to evaluate the photo and thermal requirements of barley crop and to correlate these temperature based indices with yield and phenology of the crop.

MATERIAL AND METHODS

Field studies with three barley varieties (PL I72, PL 426 and PL 807) under three dates of sowings (D_1-16th October, D_2-15th November and D_3-15th December) were conducted during *rabi* 20012-13 at the Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (30°54'N; 74°48'E and 247 meter above the mean sea level). The soil of the experimental farm was loamy sand in texture, low in available N, organic carbon, medium in available P and high in available K. The crop was sown at 22.5 cm row spacing using 87.5 kg seed per hectare. Three nitrogen levels (75, 100 and 125 % of recommended dose of nitrogen, 62.5 kg/ha) were included in the sub-sub plot and 30 kg P_2O_5 per hectare was drilled uniformly at the time of

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sowing. Nitrogen levels did not cause much variation in the phenological calendar of the crop. Hence results were averaged over nitrogen levels The phenological stages of the crop were recorded when 50 per cent of the tagged plants showed occurrence of particular phenophase (complete emergence, tillering, jointing, booting, heading and maturity). Agroclimatic indices namely growing degree days, heliothermal units, photothermal units and heat use efficiency were computed as per the following formulae suggested by Nuttonson (1955):

$$\text{Growing degree days (°C days)} = \frac{(T_{max} + T_{min})}{2} - T_b$$

Where, T_{max} = Daily maximum temperature (°C)

T_{min} = Daily minimum temperature (°C)

T_b = Base temperature (4.4°C)

The heliothermal units (HTU), the product of GDD and corresponding actual sunshine hours for that day were computed on daily basis and summed up:

$$\text{Accumulated HTU} = \sum_{i=1}^{n} \text{GDD x Actual sunshine hours}$$

The photothermal units (PTU), the product of GDD and corresponding day length for the day were computed on daily basis and summed up:

Where day length refers to maximum possible sunshine hours.

Accumulated PTU = GDD x Day length

Growing degree day, heliothermal units and photothermal units were accumulated from the date of sowing to each date of sampling and a particular date of phenophase to give accumulated indices.

The heat use efficiency (HUE) for total dry matter was obtained as under:

$$\text{Heat Use Efficiency (kg/ha/°C days)} = \frac{\text{Seed or dry matter yield (kg/ha)}}{\text{AGDD (°C day)}}$$

AGDD = Accumulated growing degree days (°C days)

Phenophasic models are the linear regression models between days taken to attain different phenological stages and heat units consumed by the crop derived for predicting the onset of any particular phenophase based on growing degree days or photothermal units or heliothermal units. Similar regression models were developed in the present investigation for predicting phenology of barley varieties under different dates of sowing as were developed by Hundal and Kingra (2000) for soybean crop.

RESULTS AND DISCUSSION

Phenological Behaviour: Time taken for completion of crop emergence was greatly influenced by date of sowing. Crop sown on 16th October took eight days for completion of emergence. Likewise, time taken for completion of emergence followed the same pattern in other dates of sowing. Subsequently the crop growth and development was also slowed down due to low temperature. Duration of October sown crop ranged from 162 to 168 days which was reduced to 140 to 145 day in November sown and 115 to 120 days in December sown. It was observed that the delay in sowing caused reduction in the vegetative phase and reproductive phase but proportionate reduction in reproductive phase was more than vegetative phase. Similar results were reported by Hundal and Sandhu (1992).Variety PL 807 sown on 16th October, took maximum number of days (44) between jointing and boot stage whereas, variety PL 426 took minimum 26 days. Duration between jointing to booting stage was reduced in all the varieties with delay in sowing. The effect was more pronounced on the crop sown in 15th December. The interval between heading stage to maturity stage was from 64 and 82 days for variety PL 807 and PL 426 days respectively in October sown crop which was reduced to 53 and 58 days for the these variety in November sown crop and 34 and 39 days in December sown crop, which clearly indicates that delayed sowing caused relatively more reduction in the reproductive phase. Varieties differ in their genetic makeup from one another. Hence, there reaction towards the growth factors such as nutrients and biotic factors also varies. Varietal differences for attainment of various phenophases were also reported by (Sardana and Zhang, 2004; Kingra and Kaur, 2013 & Kingra *et al.*, 2011)

Growing Degree Days (GDD): All the varieties consumed same number of degree days for emergence (Fig.1). The GDD consumption for emergence increased progressively with delay in sowing from 15th November to 15th December. The three varieties exhibited differential response to GDD after emergence. Variety PL 807 consumed the highest (477°C day) number of GDD up to tillering and PL 426 consumed minimum (367°C day) under first date of sowing. This differential behaviour of the varieties continues till harvest. All the three varieties behaved like in the subsequent date of sowing. Similar results were reported by Kingra and Kaur (2012a).

Photo Thermal Units (PTU): All the varieties consumed same number of degree days for emergence (Fig. 1). The PTU consumption for emergence increased progressively with delay in sowing from 15th November to 15th December. The three varieties exhibited differential response to PTU after emergence. Variety PL 807 consumed the highest PTU up to tillering and PL 426 consumed minimum under first date of sowing this differential behaviour of the varieties continues till harvest. All the three varieties

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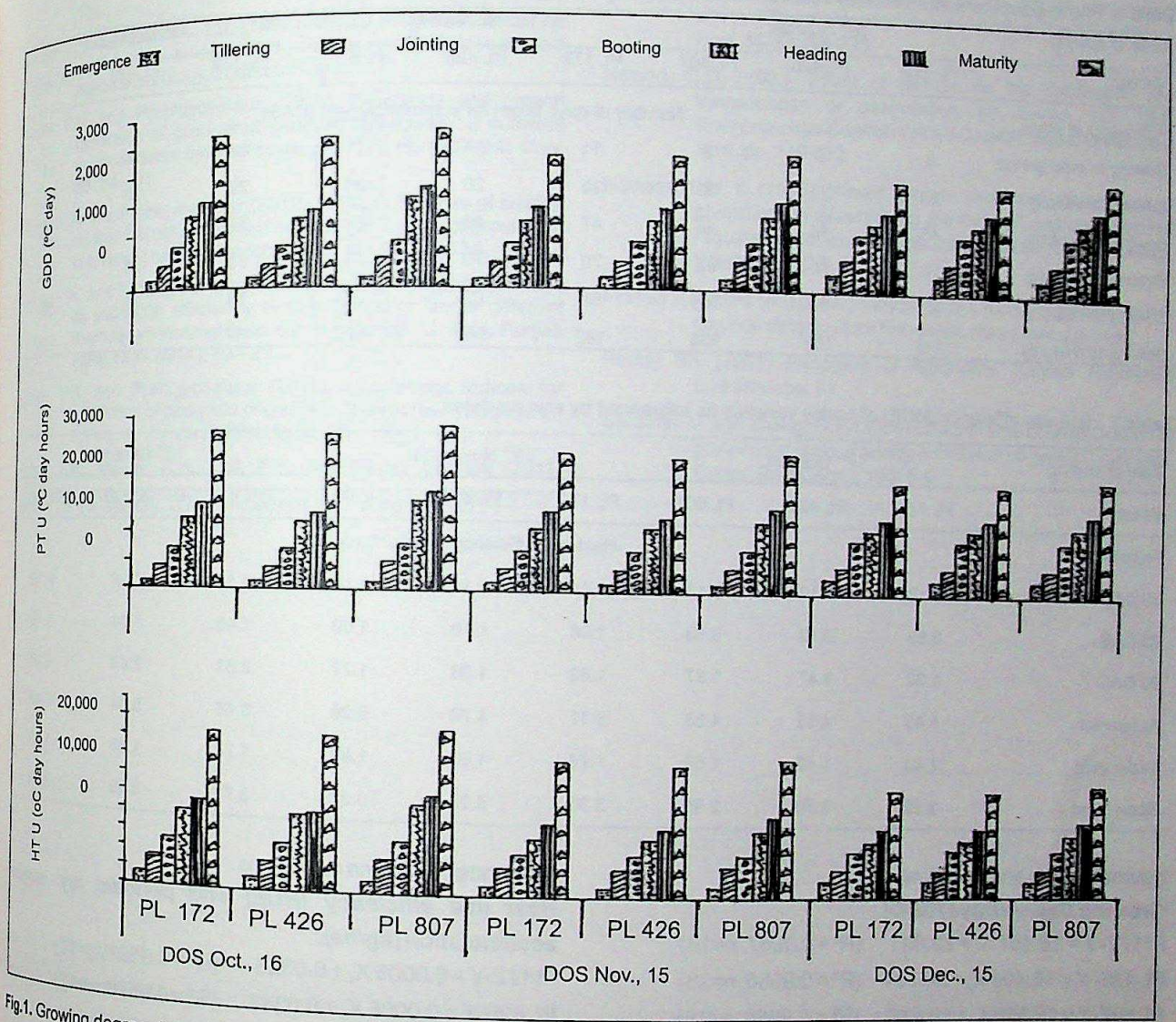

Fig.1. Growing degree days (GDD), photo-thermal (PTU) and helio-thermal units (HTU) accumulated by barley varieties as influenced by dates of sowing (DOS)

behaved like in the subsequent two (D_1 and D_2) date of sowing. However, variety 426 consumed the highest PTU in tillering stage and PL 172 consumed minimum under third date of sowing.

Helio Thermal Units (HTU): All the varieties consumed same number of degree days for emergence. The HTU consumption for emergence increased progressively with delay in sowing from 15th November to 15th December. The three varieties exhibited differential response to HTU after emergence which is evident from Fig. 1. Variety PL 807 consumed the highest HTU up to tillering and PL 426 consumed minimum under first date of sowing this differential behaviour of the varieties continues till harvest. All the three varieties behaved like in the subsequent date of sowing. Kingra and Kaur (2012a) also reported varietal differences in accumulating HTU and PTU by groundnut cultivars.

Heat Use Efficiency (HUE): The HUE kept on increasing from 30 DAS till harvest, maturity of the crop for all the varieties and dates of sowing (Table 2). Variety PL 426 was found more efficient in terms of HUE up to 90 days of crop growth whereas after that PL 807 was found more efficient. Heat use efficiency of PL 807 for production of grain, straw and total dry matter (grain + straw) was the highest in all the three date of sowing and that of variety PL 426 was the lowest.

Development of Phenophasic Models: Two linear regression models taking the phenophasic data, of three dates of sowing for three varieties (separate) derived for predicting the onset of any particular phenophase based on growing degree days, helio thermal units and photo

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Table 1. Phenological calendar of barley varieties as influenced by sowing dates

Date of sowing	16th October			15th November			15th December		
Variety	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807
Phenological stage	Number of days taken for commencement (DAS)								
Sowing to emergence	8	8	8	11	11	11	14	14	14
Sowing to tillering	23	21	28	26	26	28	29	28	28
Sowing to jointing	45	44	48	47	46	48	57	58	58
Sowing to booting	76	70	92	70	70	79	68	68	72
Sowing to heading	90	80	104	86	82	92	78	79	86
Sowing to maturity	165	162	168	142	140	145	117	115	120

Table 2. Heat use efficiency (HUE) of barley varieties as influenced by sowing dates

Date of sowing	16th October			15th November			15th December		
Variety	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807	PL 172	PL 426	PL 807
Treatment	Heat use efficiency (kg/ha/°C day)								
30 DAS	0.12	0.12	0.12	0.14	0.14	0.14	0.15	0.15	0.15
60 DAS	0.88	0.92	0.83	1.06	1.10	1.00	1.19	1.24	1.10
90 DAS	1.39	1.47	1.37	1.80	1.88	1.77	2.31	2.43	2.26
At harvest	4.40	4.13	4.53	5.11	4.76	5.26	5.45	5.04	5.60
Grain yield	1.48	1.42	1.59	1.76	1.69	1.88	1.74	1.65	1.88
Straw yield	2.92	2.70	2.95	3.35	3.07	3.37	3.72	3.39	3.73

thermal units is shown below.

Growing Degree Days (GDD)

PI 172-$Y = 15.467 X_1 + 22.041$ ($R^2 = 0.9987$, n=18)

PL 426-$Y = 15.406 X_1 + 24.264$ ($R^2 = 0.9986$, n=18)

PL 807-$Y = 15.511 X_1 + 19.437$ ($R^2 = 0.9986$, n=18)

Photothermal Units (PTU)

PI 172-$Y = 167.3 X_2 + 17.254$ ($R^2 = 0.998$, n=18)

PL 426-$Y = 166.22 X_2 + 32.22$ ($R^2 = 0.9979$, n=18)

PL 807-$Y = 167.98 X_2 + 56.441$ ($R^2 = 0.9977$, n=18)

Heliothermal Units (HTU)

PI 172-$Y = 96.316 X_3 + 154.85$ ($R^2 = 0.9809$, n=18)

PL 426-$Y = 95.372 X_3 + 232.75$ ($R^2 = 0.9768$, n=18)

PL 807-$Y = 97.387 X_3 + 107.83$ ($R^2 = 0.9849$, n=18)

Where,

Y is number of days predicted for attainment of particular stage.

X_1, X_2 and X_3 are AGDD, APTU and AHTU, respectively.

The model indicated that GDD, PTU and HTU accounted for more than 97 per cent variation in the onset of different phenophases for three barley varieties under investigation. Hundal and Kingra (2000) also reported AGDD as the best index to predict various phenophase for soybean crop under Ludhiana conditions.

Heat use efficiency (HUE) and periodic dry matter accumulation (kg/ha):

PI 172-$Y = 0.0005 X_4 + 0.0325$ ($R^2 = 0.9597$, n=12)

PL 426-$Y = 0.0005 X_4 + 0.0343$ ($R^2 = 0.9576$, n=12)

PL 807-$Y = 0.0004 X_4 + 0.0294$ ($R^2 = 0.963$, n=12)

Where,

Y is periodic dry matter accumulation for attainment of particular stage.

X_1, X_2 and X_3 are periodic AHUE, respectively.

The model indicated that periodic AHUE accounted for more than 94 per cent variation in the onset of different periodic dry matter accumulation for three barley varieties under investigation. Kingra and Kaur (2011) also reported significant linear relationship ($R^2 = 0.968$) between HTU and dry matter accumulation of groundnut crop. By using such models, the dates of occurrence of various phenophases, growth and yield of crops can be predicted by accumulating real time temperature.

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Estimation of Groundwater Recharge Using Well Recharging Unit in Parasai- Sindh Watershed of SAT Region of India

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Abstract: Field study was undertaken in Parasai – Sindh watershed to investigate the ground water recharge possibilities of shallow dug well by well recharging unit. Water table rise of about 14.87 per cent was recorded as compared to control well after getting rainfall of 100 mm of cumulative rainfall. At 270 mm cumulative rainfall, the water column of treated well was recorded 32 per cent higher as compared to control. When cumulative rainfall of watershed was 506 mm, the water column of treated well was found 21 per cent higher than control well and at 700 mm of cumulative rainfall the difference in water level of both treated and control well was found very less. The change in ground water storage volume of watershed during pre and post monsoon by treated and control well was observed 1143 and 1023 m^3.

Key Words: Rainfall, Shallow Dug Well, Well Recharging Unit, Ground Water Recharge

Groundwater has now become a major natural resource contributing the water supply system in the country like India but groundwater is actually under strong human pressures in many countries. Groundwater fulfils about 60% irrigation and 80% drinking water requirements of India (CWC, 2007). Though groundwater has played a vital role in stabilizing Indian agriculture but indiscriminate use has resulted in fast depletion and degradation of this key natural resource. Water table is declining at an alarming rate in about 15% of India's geographical area (Kamra and Sharma, 2011).

Due to over-reliance and rapid development of irrigation using ground water, the unsustainable and over-exploitation of ground water has been observed in several parts of the country especially in the North-Western States of Punjab, Haryana and Rajasthan, and in the hard-rock regions of Peninsular India. Artificial groundwater recharge involves regulated movement of excess surface water through a constructed recharge structure into an aquifer. The recharge structures must be combined with an efficient filtering unit to prevent entry of physical impurities of the run-off water into the recharge system.The filtration unit must perform effectively to get potential benefits from the installed recharge structures it depends on hydraulic efficiency and the filtration effectiveness (Martinson and Thomas, 2005).

The objective of this paper is to investigate the possibilities and prospects of ground water recharge and to identify the potentiality of rainwater for recharging shallow dug well in semi arid tropics of India.

MATERIAL AND METHODS

The study was conducted at Parasai - Sindh watershed area of 1246 hectares. Study area Consitituted three villages namely Parasai, Chhatpur and Bachhauni which is located in Babina block of Jhansi District, Bundelkhand region (part of Uttar Pradesh), Semi-arid tropics (SAT) of Central India.The watershed located between 25 ° 23' 47.6" - 25 ° 27' 05.1" latitude and 78° 20' 06.5" - 78° 22' 33.0" longitude (Fig. 1). Watershed has a semi-arid tropical climate and is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. The annual rainfall of the watershed region varies from 800 to 1300 mm. The landscape is rugged, featuring undulating terrain with low rocky outcrops, narrow valleys and plains. Surface rocks are predominantly granite of the Lower Pre Cambrian/Archaen period. Some Dharwarian and Vindhayan rocks present in the region contain minerals of economic value. Sandstone, shales and limestone of high quality, along with Dyhes, Sills and the famous pink Archaean gneiss rocks, are also found in places.

Study is dependent upon several factors including local hydrogeology, topography, daily rainfall data during monsoon season and also types of facilities available for artificial recharge of groundwater through rainwater harvesting. Daily rainfall data was recorded withtwo automatic rain gauges, which was installed in upper ridge and middle ridge of watershed. Based on the land use, drainage network, slope, geomorphology and lithology of the

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area, twenty three dug wells were identified and proposed for recharging the ground water in whole watershed (Fig. 2). Two open shallow dug wells were selected for the comparative study for recharging. These wells were either gone dry, or the water levels have declined considerably during summer months. The field observation was carried out by monitoring water level in these wells during monsoon season. One well was used for treatment (installing well recharging unit) and other one used for control. Both wells were situated at upper reach of watershed at equal distances from drain where slope was high and water availability was very less for drinking and irrigation during summer months. The depth and diameter of both selected wells was equal i.e., 10.5 and 6 m, respectively. The recharging unit was designed for artificial recharge. It consist sediment trap pit and recharging filter (Fig.3). Recharging filter having six layer of fine sand, coarse sand, small concrete grit, concrete grit, pebble and stone of 0.2 mm, 2 mm, 2 cm, 5 cm, 10 cm and 20 cm, respectively. Recharge filter was installed at 3m away from the well. Rain water was allowed to pass through plug and water stored in sediment pit. Sediment settled in sediment pit and water passes through filter unit. Filtered water was guided through a pipe to the bottom of well, below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.

The water level of selected wells was monitored on daily basis during whole monsoon for groundwater recharge estimation. Ground water recharge in selected well of watershed during monsoon season is estimated by water level fluctuation during before and after monsoon and specific yield method by well accepted technique (GREC, 1997).

Ground water level fluctuation and specific yield method:

S=Area x Average water table fluctuation x Specific yield

Where, S = change in ground water storage volume during pre and post monsoon period

RESULTS AND DISCUSSION

Digital Elevation Model (DEM) and slope gives an idea about the topography and level of inclination of the study

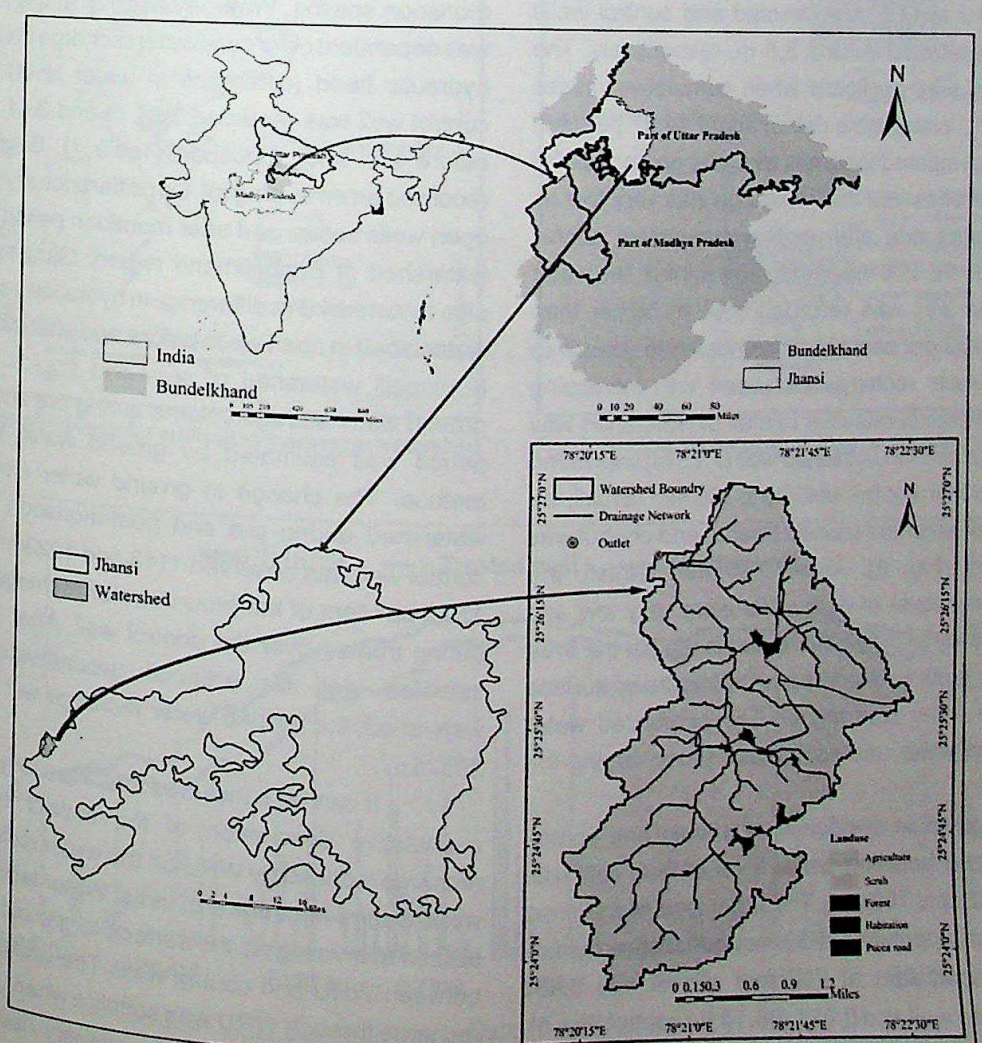

Fig. 1. Location Map of Parasai-Singh watershed

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area. Land use of Parasai-Sindh watershed was categorized in six types. Maximum area is under agricultural land (88.7%) followed by scrub land (5.29%), drainage network (3.6%), road (1.15%), habitat (0.89%) and very small area covered by forest (0.45%).

Based on DEM and slope, the different types of artificial recharge structures were proposed in watershed area. In alluvial as well as hard rock areas, where the dug wells have gone either dry or the water level have declined can be used as an artificial recharge structure, by diverting groundwater reservoir, tank water, canal water, etc. to the dried aquifer. Existing wells of the study area were recharged by dug well method. Well recharging priority was based on the wells, which are situated at upper ridge of watershed. In study area, there are 200 wells present out of these 25% of the wells were dried up and this dried well has given the first priority. Since these wells already exist, this method can be easily adopted without much expenditure. The artificial recharge of ground water was done by using well recharging unit (WRU) in the watershed. The data was collected on daily basis during monsoon season (June to Oct.).

The water level of both treated and control wells were recorded initially 3.7 m and 3.5 m, respectively. The recharging of well was negligible when cumulative rainfall was below 50 mm. Water table rise of about 14.87 per cent was recorded as compared to control well after getting rainfall of 100 mm. It was observed that, recharge was very fast as compared to control one after getting cumulative rainfall more than 100 mm. At, 270 mm cumulative rainfall, the water column of treated well was recorded 1.46 m higher than control and it was 32 per cent higher compared to control. In general, groundwater recharge increased with increasing rainfall amount. When cumulative rainfall of watershed was 506 mm, the water column of treated well (7.25 m) was found 21 per cent higher than control well. Up to 700 mm rainfall, the difference in water column between treated and control was recorded 0.98 m (Fig. 4). Above 700 mm rainfall, the fluctuation of water level of both wells were very low and recharging efficiency of WRU decreased because the area around well was saturated and percolation rate of surface and sub-surface water was higher. The percolated water increased ground water and contributed to recharging the open dug well.

The regression coefficient of treated and control well were analyzed between water level of both well with cumulative rainfall upto 700 mm. The water level of wells was separated at each approximate 50 mm cumulative rainfall. The regression coefficient at 700 mm rainfall was 0.984 (98.40%) for treated well and 0.981 (98.10 %) control (Fig. 5). Groundwater recharge increased linearly in control well whereas, groundwater recharge in treated well reached to its saturation (7.93 m) with 855 mm cumulative rainfall. Storage capacity of groundwater aquifer is limited therefore, additional rainfall could not help in further groundwater recharge. Above 700 mm rainfall, the fluctuation of water level of both wells was very low and recharging efficiency of WRU was decreased because the area around both the wells was saturated. It was observed that after 1100 mm of cumulative rainfall difference in water column of both selected well was negligible. At the end of rainy season (31st October) when cumulative rainfall was 1421.30 mm, water level of both wells coincided (Fig. 6). Thus the artificial groundwater recharge through WRU was effective up to 1100 mm rainfall and artificial groundwater recharge through WRU was very useful for semi-arid regions which receive low rainfall. It is also effective in upper reaches of high rainfall region where slope is higher and soil depth is less.

The results of this study indicate that in pre-monsoon, water level of treated wells was 3.70 m, whereas, 3.50 m was recorded in control well.The water level of treated and control well were recorded 7.51 and 6.91m, in post-monsoon season. Water availability at the end of monsoon was dependent on groundwater recharge in current year. The hydraulic head (difference in water level) of treated and control well was recorded 3.81 m and 3.41 m, respectively before and after monsoon (Table 1). Singh *et al.* (2014) recorded on an average 4.0 m difference in hydraulic head in open wells before and after monsoon period for Garhkundar watershed of Bundelkhand region. Garg and Wani (2013) also reported 4.5 m difference in hydraulic head (difference in water label) in open wells before and after monsoon period in Kothapalli watershed of semi-arid tropics. The change in ground water storage volume during pre and post-monsoon period was estimated by ground water level fluctuation method. The change in ground water storage volume of watershed during pre and post-monsoon by treated and control well was observed 1143 and 1023 m^3. Approximately 11.73 per cent of the ground water recharge was estimated during treated over the control well. After the treatment of selected well for artificial groundwater recharge in watershed, the ground water recharge will be increased by 28575 m^3.

It can be concluded that this study provided a vital quantitative description of the impact of ground water recharge induced by WRU on the water supply and quality of wells in semi-arid region of India. Water table of dug well was utilized to investigate the surface to groundwater interaction between WRU and control wells.The artificial ground water recharge through WRU was suitable where, annual rainfall is up to 1100 mm thus, WRU was very useful for semi arid

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Table 1. Different parameters of water potentiality

S. No.	Water potentiality parameters	Treated	Control
1.	Water level (m) well Pre-monsoon	3.70	3.50
2.	Water level (m) well Post-monsoon	7.51	6.91
3.	Difference in water level (m)	3.81	3.41
4.	Change in ground water storage volume during pre and post - monsoon period by water table fluctuation method (m^3 $year^{-1}$)	1143.00	1023.00
5.	Increasing ground water storage volume in wells (per cent) through treatment	11.73	-

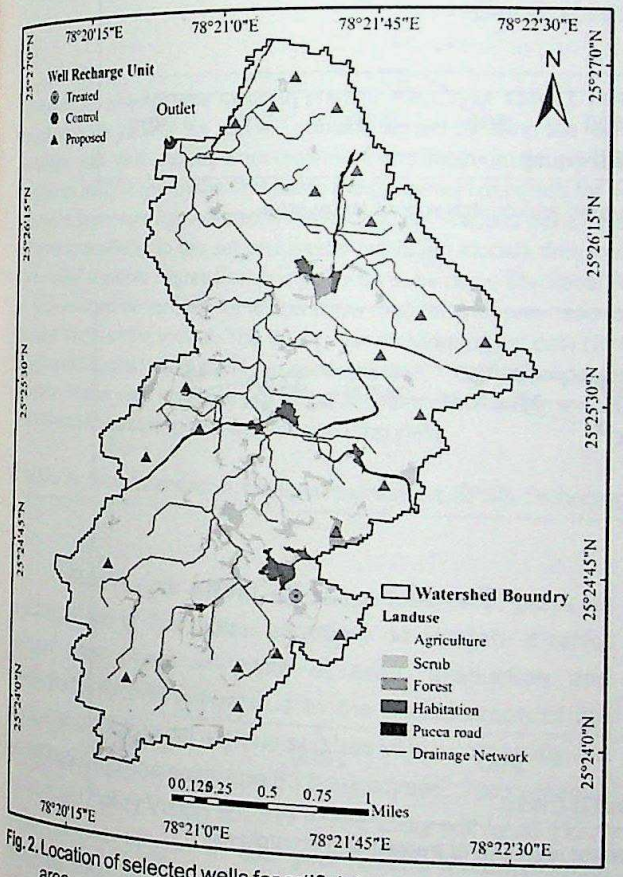

Fig. 2. Location of selected wells for artificial recharging in watershed area

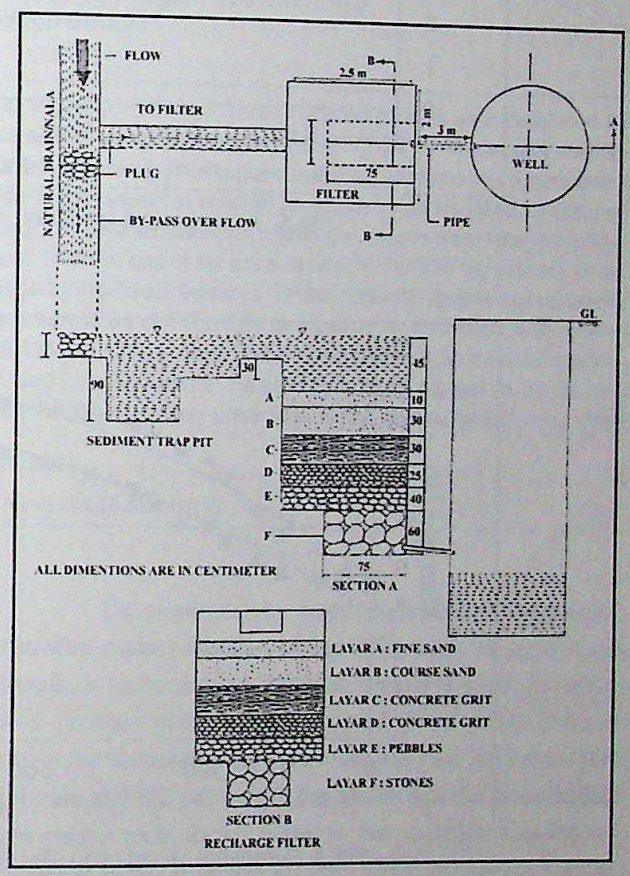

Fig. 3. Artificial recharging of shallow dug well with recharge filter

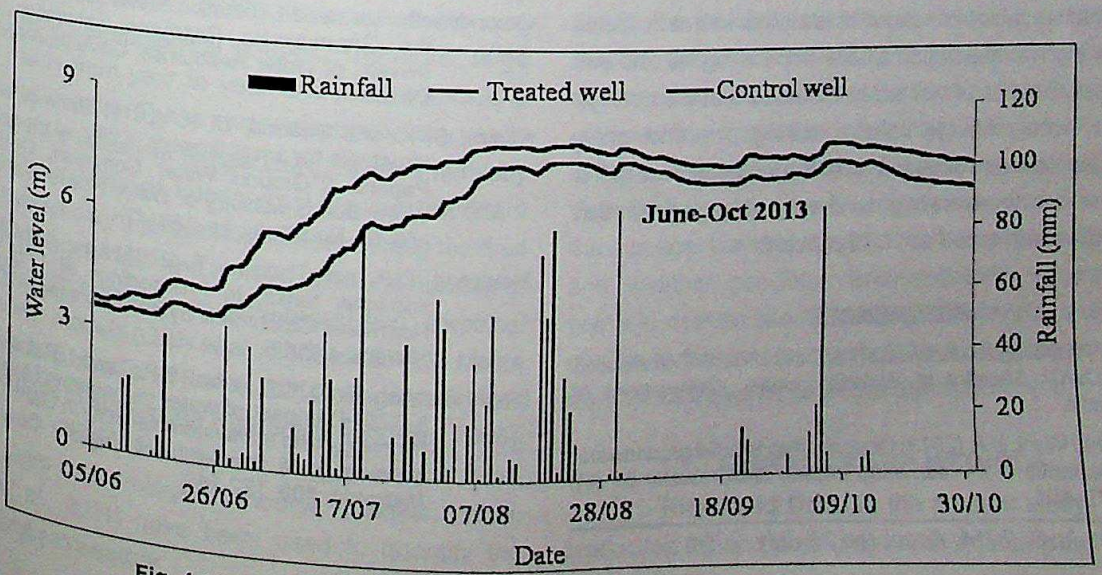

Fig. 4. Water level situation in treated well as compare to control well with rainfall

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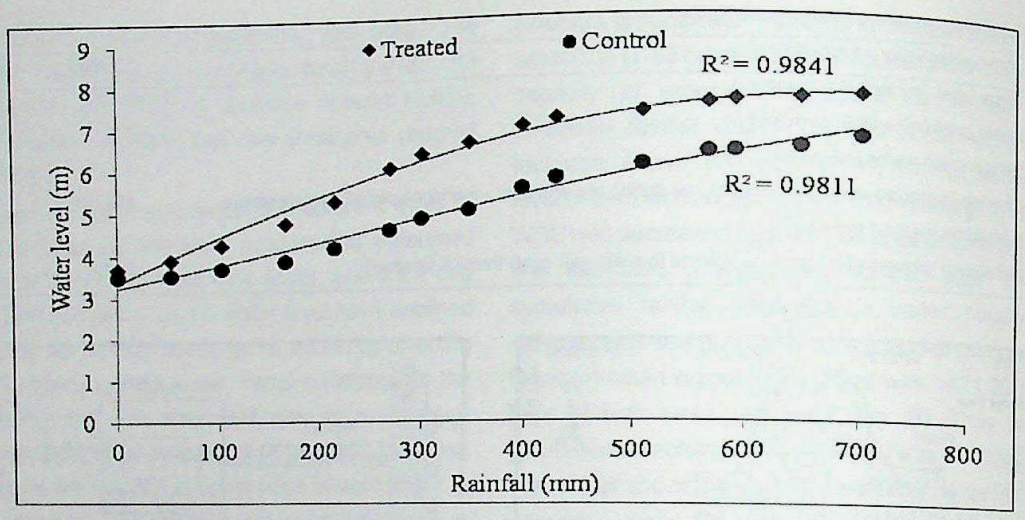

Fig. 5. The regression coefficient of treated and control well of study area

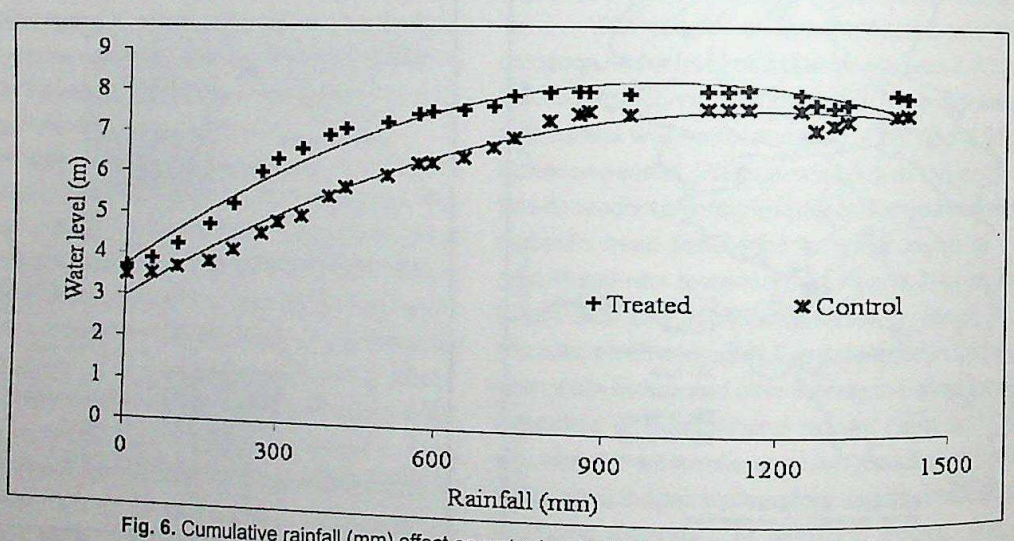

Fig. 6. Cumulative rainfall (mm) effect on water level (m) of treated and control well

regions which receive low rainfall. It is also effective in upper reaches of high rainfall region where slope is higher and soil depth is less. Results of this study indicated that the change in ground water storage volume during pre and post-monsoon period was increased after the installation of WRU in the watershed. Increase in ground water storage volume in treated well was recorded as 11.73 per cent.

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Indian Journal of Ecology

Meteorological Model for Rice Yield Forecasting in Ludhiana Region

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Abstract: An attempt was made to predict rice (*Oryza sativa* L.) yield by regression models. Three statistical models were developed for forecasting the yield of the rice in Ludhiana district by using the rice yield as well as meteorological data (1972-2012). The weekly weather variables used for this study were maximum and minimum temperature, relative humidity (morning and evening), sunshine hours, rainfall and number of rainy days. In the first basic model, sensitive period for rice yield with respect to weather parameters was identified for different weather parameters for selected windows and correlations were developed. The selected sensitive weekly parameters were taken for further regression analysis. In the second model (modified model), time trend was taken as one of the extra variable in multiple regressions. In the third model, multiple regression analysis was done using Statistical Package for the Social Sciences (SPSS) software. Regression equations were developed separately for all the three models and were used to predict the rice yield. The data for a period of (1972-2009) was used to develop the forecast model. The three year meteorological data (2010-2012) was used to validate the models. Among all the three models, basic model explained up to 64 per cent variation, modified model explained 67 per cent and SPSS model predicted highest i.e. 88 per cent variation in rice yield due to weather parameters. The results revealed that SPSS accurately predicted the rice yield as compared to other models and it had strong relation with rice crop yield.

Key Words: Rice, Correlation, Multiple Regression, SPSS, Technology Trend, Yield Forecasting

Rice (*Oryza sativa*), as staple food crop, plays an important role in the Indian economy. In Punjab, it ranks second after wheat in terms of area, production and productivity. Rice is indigenous to the humid areas of the tropical and subtropical regions and has vide adaptability. On an average, Indians consume 83 kg rice year^{-1}. According to Agricultural Policy Vision 2020 of ICAR, India will need 112.4 million tonnes of rice in the year 2020. Meteorological variables such as rainfall, temperature, etc. predominantly affect the rice yield (Ji *et al.*, 2007). Weather affects crop growth at different phenological phases. Therefore, large variation in yields from year to year and place-to-place is attributed to the weather. These parameters may vary yearly and intra and inter seasonal temperature, relative humidity and sunshine hour deviation from normal are very important as these variations play a pivotal role in determining the final crop yields (Prabhjyot-Kaur and Hundal, 2009). A number of statistical techniques such as multiple regression, empirical linear regression models (Qian *et al.*, 2009), CERES- Maize model for maize (Lobell and Burke, 2010), regression and probability models in sugarcane (Aggarwal and Jain, 1996), Ceres-Rice and ORYZA1N for rice (Aggarwal and Mall, 2002) and agro-meteorological models (Walker, 1989; Mukherjee *et al.*, 2011) have been used to quantify the response of crops to weather.

Development of good forecasting techniques requires accommodation of variability such as agricultural inputs or technological changes, meteorological variability and random noise into the model. Crop productivity is projected to decrease for the increase of local temperature at the rate of 0.6°C per year in the region and the crop models are useful tools for considering the complex interactions between a range of factors that affect crop performance, including weather and crop management (Shamim *et al.*, 2012). Pre-harvest estimates of rice yield are of immense help to the policy makers and the planners for making advance planning for food and other relief measures in areas of impending crop failure, planning food imports and exports in case of an anticipated deficit and surplus, respectively. With the help of the satellites it has become easier to know the acreage, stand of the crop, disease incidence, irrigation and weather condition instantaneously. Keeping these points in view, an attempt was made to develop a regression models to forecast the yield of rice taking into account the weather variables for Ludhiana district of Punjab.

MATERIALS AND METHODS

Rice Yield Data: In the present study, the yearly production (q) and area (ha) under rice crop for the period 1972 to 2012 in respect of Ludhiana district were collected

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from Statistical Abstract of Punjab. For each year, the total production of the district was divided by the total acreage to calculate the rice productivity.

Weather Data: Weather parameters influence the crop growth and yield. Series weekly data of different weather elements (maximum temperature, minimum temperature, rainfall, sunshine hour, number of rainy days, morning and evening relative humidity) for the years 1972 to 2012 were collected from the meteorological observatory installed at School of Climate Change and Agricultural Meteorology, PAU, Ludhiana. The data were collected for the months covering life cycle of the crop, except the harvesting period (23rd week to 39th standard meteorological week), since the forecast is to be given before harvesting.

Yield Forecast Models: The correlation analysis was carried out using Pearson correlation technique and the statistical model was developed using multi-regression method. All the three models were developed from a data series of 37 years (1972 to 2009) and the model was verified with independent data for the years from 2010 to 2012, outside their sampling series. The performance of the model was examined critically by computing percentage deviations of estimates and forecast yield figures.

Basic Model (Model 1): A basic model was developed using weather parameters without including technological trend. The average reported crop-yield was taken as dependent variable with weather parameters as independent variables. In the correlation and regression technique, significant correlation between yield and the meteorological parameters was identified. The critical periods when weather parameters exert significant influence on yield were located by analyzing the correlation coefficients for statistical and phenological significance. Out of all the periods, the sensitive periods of statistical and phenological significance were selected in terms of standard meteorological weeks (SMWs) for regression analysis.

Modified Model (Model 2): Secondly, a modified model was obtained by introducing an assumed technological trend in the basic model keeping other independent variables constant. The development of modified model was intended to improve the accuracy of forecast of rice yield by superimposing the impact of agricultural technology in the form of linear time scale dummy variable.

SPSS Model (Model 3): The third model was based on analyzing regression using SPSS (Statistical Product and Service Solutions) software. Pearson's correlations between observed rice yield and weather parameters and with combinations of weather parameters were computed. Sum of weather parameters and sum product of different weather parameters and correlation coefficient was derived. Multiple regressions between dependent variable (yield) and independent variables (time, sum and sum products for different weather parameters) were worked out using SPSS software. Regression equation was written using the regression formula for all the three models as follows:

$$Y_e = a_0 + \sum_{i=1}^{n} a_i x_i + \sum a_j x_j$$

Where,

Y_e = Estimated yield (kg/ha)

a_0 = Regression constant

a_i = Regression coefficients for meteorological predictor variables

x_i = i^{th} meteorological predictor variable i = 1, 2, ...n

a_j = Regression coefficients for technological trend variables.

x_j = j^{th} technological trend variable

RESULTS AND DISCUSSION

The three different yield forecast models were developed based on different weather variables affecting crop yield, then correlated with rice crop yield on weekly basis and the sensitive windows for further processing were worked out. The normal weather conditions required for rice crop at Ludhiana are presented in Fig 1 (a & b).

Out of all the periods, the sensitive periods of statistical and phenological significance were selected in terms of standard meteorological weeks (SMWs) for regression analysis (Table 1). The sensitive periods for rice crop represented maximum tillering, panicle initiation, heading and anthesis. The maximum and minimum temperature, sunshine hours and morning and evening relative humidity showed positive effect on the rice yield

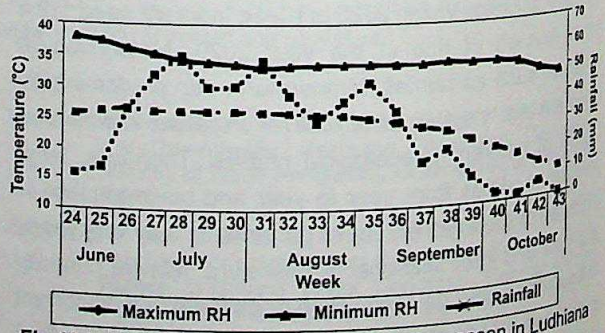

Fig 1(a). Normal weather conditions for rice season in Ludhiana

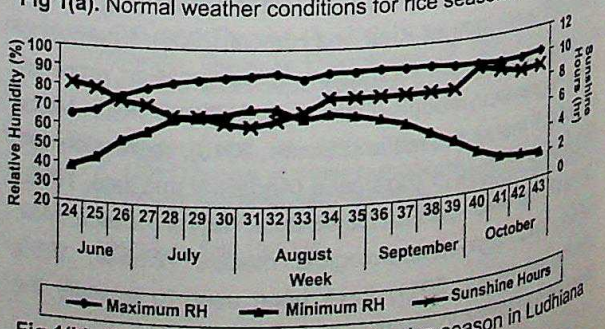

Fig 1(b). Normal weather conditions for rice season in Ludhiana

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during the crop growth season, whereas, total rainfall and number of rainy days showed negative effect on the rice yield during late vegetative and early reproductive stages.

The correlation coefficients were worked out for the rice crop season by taking into account the meteorological data on weekly basis. It was found that sunshine hours were positively and significantly (p=0.05) correlated with grain yield (Table 2). The other meteorological parameters like maximum temperature and minimum temperature also exhibited a similar trend during vegetative and reproductive stages. The rest of the weather parameters like relative humidity, rainfall and number of rainy days were significantly and negatively correlated with grain yield.

The final yield forecast models constructed by using important weather variables have been presented as below.

Model 1: In the basic model, the weekly weather data at critical periods were correlated with the yield and then the sensitive periods were taken for further analysis to develop regression equation and the regression expression is as follows:

Yield = (-5082.78) + Tmax32 *115.14 + Tmin27 * 75.37 + Rain27 *(-2.27) + rainy days 33 * 219.73 + RH max 30 * 34.22 + RH min 37 and 38 * 5.74 + SSH 37 *(-55.03)

R^2=64%

This model explains 64 per cent of variation in the rice yield due to weather variables. The per cent error ranged between minimum -29.3 per cent to 12.5 per cent. The forecasted yield and per cent error of 37 years based on above regression equation is given in Table 3.

Model 2: In second model (Modified model), the weather parameters in critical periods along with technology trend variable were used through multiple regression analysis to obtain forecast equations. Improved agricultural technology necessitated the need to modify the basic model by introducing technological trend as an independent linear time scale dummy variable. The regression expression is as follows:

Yield = (-1480.32)+ Tmax 32 *85.19 + Tmin 27*13.38 + Rain 27 *(-2.03)+ Rainy days 33 *184.74 + Rmax * 32.48+ Rmain (37+38) *(-9.59) +SSH*(-87.87)+ Technology* 0.23

R^2 = 67%

Upon incorporating technology trend in the equation, the R^2 value increased to 67 per cent. The error per cent for modified model ranged between -29.2 per cent to 10.9 per cent during the study period.

Model 3 (Regression using SPSS software): The multi-regression analysis using SPSS was employed for the estimation of rice yield. The regression expression is as follows:

Regression equation = 9627.789 + Z10 * (-11.424) + Z 71 * 117.779 + Z 350 * (-0.011) + Z 370 * (-0.250) + Z 461 * 2.556 + Time * 21.544

R^2 = 88%

Here,

Z10 is sum of Tmax, Z71 is sum product of sunshine hours, Z350 is sum of rain, *Relative humidity (morning), Z370 is rain, *sunshine hours and Z461 is rainy days, * Relative

Table 1. Sensitive periods for rice crop and effect of weather variables on rice yield

Meteorological parameters	Sensitive period (SMWs)	Stage of rice crop	Effect on rice yield
Maximum temperature	32	Early reproductive stage	+ve
Minimum temperature	27	Late vegetative stage	+ve
Rainfall	27	Late vegetative stage	-ve
Number of rainy days	33	Early reproductive stage	-ve
Sunshine hours	37	Late reproductive stage	+ve
Maximum relative humidity	30	Early reproductive stage	+ve
Minimum relative humidity	37,38	Late reproductive stage	+ve

Table 2: Correlation coefficients of rice yield with weekly meteorological parameters at Ludhiana (*Kharif* 1972 to 2012)

Crop growth phase	Temperature (°C)		Sunshine Hour (hr)	Relative humidity (%)		Rainfall (mm)	Rainy Day
	Tmax	Tmin		RH max	RH min		
Vegetative phase	0.45	0.04	0.45	-0.50	-0.34	-0.46	-0.42
Reproductive phase	0.24	0.10	0.30	-0.44	-0.29	-0.11	-0.50

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Table 3. Validation of statistical models for yield prediction of rice crop

Year	Actual yield (Kg/ha)	Forecasted yield (Kg/ha)	% deviation
Model 1 (Basic model)			
2010	4409	4025	8.7
2011	4257	4613	-8.4
2012	4548	4640	-2.0
Model 2 (Modified model)			
2010	4409	4066	7.8
2011	4257	4583	-7.7
2012	4548	4506	0.9
Model 3 (SPSS model)			
2010	4409	4100	7.0
2011	4257	4446	-4.4
2012	4548	4075	10.4

humidity (evening)

Results were consistent with previous work by Huang *et al.* (2013) and Prabhakaran *et al.* (2013) where, the regression equation showed that maximum temperature, sunshine hours, combination of rain and relative humidity (morning), combination of rain and sunshine hours, combination of rainy days and relative humidity (evening) played an important role on rice yield in Ludhiana region. The per cent error ranged between minimum -12.4% in year 1998 and maximum 8.4% in year 1984. The forecasted yield and per cent error based on above regression equation is given in Table 4. The forecasted yield of rice for year 2012 is 4075 kg/ha and actual yield is 4548 kg/ha. R^2 value is 88% indicates that weather variables are able to explain 88% of

Table 4. Forecasted yield and error per cent of three different models from year 1972 to 2009

Year	Actual yield (kg /ha)	Model 1		Model 2		Model 3	
		Forecasted yield (kg /ha)	% Error	Forecasted yield (kg /ha)	% Error	Forecasted yield (kg /ha)	% Error
1972	2342	2262	3.4	2288	2.3	2339	0.1
1973	3123	3256	-4.3	3179	-1.8	2978	4.7
1974	2979	3419	-14.8	3394	-13.9	3212	-7.8
1975	3383	3590	-6.1	3503	-3.6	3315	2
1976	3614	3385	6.3	3296	8.8	3671	-1.6
1977	3720	3771	-1.4	3567	4.1	3761	-1.1
1978	3776	3668	2.9	3485	7.7	3542	6.2
1979	3443	3556	-3.3	3519	-2.2	3827	-11.2
1980	3790	3661	3.4	3523	7.0	3597	5.1
1981	4130	3931	4.8	3815	7.6	4069	1.5
1982	3941	3605	8.5	3647	7.5	3924	0.4
1983	3677	3747	-1.9	3666	0.3	3493	5
1984	3568	3501	1.9	3470	2.7	3266	8.5
1985	3812	3471	8.9	3454	9.4	3699	3
1986	4274	3784	11.5	3862	9.6	4096	4.2
1987	3927	3910	0.4	3942	-0.4	3751	4.5
1988	3242	3390	-4.6	3570	-10.1	3138	3.2
1989	4146	3825	7.7	4006	3.4	4130	0.4
1990	3673	3554	3.2	3653	0.6	3463	5.7
1991	3579	3765	-5.2	3817	-6.7	3756	-4.9
1992	4257	4004	5.9	4105	3.6	4128	3
1993	3900	3869	0.8	3863	0.9	4047	-3.8
1994	3557	4088	-14.9	4152	-16.7	3668	-3.1
1995	3231	4177	-29.3	4174	-29.2	3310	-2.4
1996	3604	3518	2.4	3685	-2.2	3362	6.7
1997	3841	3583	6.7	3734	2.8	3935	-2.4
1998	3273	3911	-19.5	3907	-19.4	3679	-12.4
1999	3611	3559	1.4	3591	0.5	3547	1.8
2000	3947	4261	-8	4229	-7.1	4265	-8.1
2001	3897	3705	4.9	3873	0.6	3886	0.3
2002	4322	4113	4.8	4103	5.1	4173	3.5
2003	4342	4573	-5.3	4506	-3.8	4197	3.3
2004	4633	4701	-1.5	4661	-0.6	4651	-0.4
2005	4521	3954	12.5	4112	9.0	4468	1.2
2006	4371	4548	-4	4482	-2.5	4589	-5
2007	4532	4073	10.1	4039	10.9	4508	0.5
2008	4469	4225	5.4	4156	7.0	4555	-1.9
2009	4693	4449	5.2	4510	3.9	4551	3

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variation in the rice yield in Ludhiana region.

Validation of the models: Three years (2010, 2011 & 2012) weather data was used for the validation of model for the prediction of rice yield for Ludhiana region. The results showed a close proximity between predicted and observed values during the validation period. The forecasted yield of three years was compared with actual yield of that particular year to calculate the error percentage. The results showed that in year 2010, all the three models predicted the yield less than the actual yield with a deviation ranges from 7 to 8.7%, but the trend was reverse in the year 2011, where all the three models showed positive deviation ranging from 4.4 to 8.4% and predicted more yield than the actual yield. Again in 2012, a different trend was noticed, where Model 1 predicted yield more than the actual, but the other two models i.e. Model 2 and Model 3 predicted lower yield than the actual yield of rice crop and higher range of deviation was found, which ranged from -2.0 to 10.4% (Table 2).

On the other hand, the error percentage for model within the model for validation period, ranged from -2.0 to 8.7 %, 0.9 to -7.7 % and -4.4 to 10.4 % for basic model, modified model and SPSS model, respectively. The error per cent of Model 2 was less than the basic model for all the three years and it was 7.8, -7.7 and 0.9 per cent for the year 2010, 2011 and 2012, respectively. The error per cent for Model 3 was 7.0, -4.4 and 10.4 per cent for year 2010, 2011 and 2012, respectively, which was quite high during 2012 since during the year 2012, the weather was quite different as compared to earlier years.

The models developed in this study provide the possibility of predicting pre-harvest estimates of rice yield for Ludhiana district and could be computed successfully in advance before the actual harvest. The predictability of the model within 10% accuracy is considered to be reliable by any crop-modelling standard. The actual output can be compared with simulated output under normal weather conditions to assess stress on the crop and thereby, could help in formulating suitable agroadvisory for the management of the crop to decrease the yield loss. Moreover, the model also computes the potential production of the crop under optimal conditions which will help in identifying regions suitable for optimal crop production in the state. The district government authorities also can make use of the forecast model developed using weather indices for obtaining accurate pre-harvest estimates of rice crop. The main beneficiaries are farmers, traders, exporters and importers.

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Fertilization Unsuitability Index for Assessing Fertilizer Induced Contamination Risk in Soils of Cotton-Wheat System of South Punjab Districts

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Abstract: In this study the fertilization unsuitability index (FUI) has been proposed for estimating soil contamination and nutrient imbalance resulting from fertilizer application at farm source. The fertilizer use data was collected directly from the selected farmers in the study area and interpolated environmental risk resulting from over fertilization was represented in spatial format using Arc GIS software. The results reported that urea was applied more than double the amount recommended for cotton and wheat cultivation where as the diammonium phosphate was applied at recommended levels in wheat and 50% above recommended dose in cotton in majority of villages in the study area. The average value of FUI was higher in cotton (527.205) in comparison to wheat (491.35) when nitrogen and phosphorus requirement of crops was met by application of urea and diammonium phosphate. Whereas the maximum FUI was reported in Muktsar district (544.52) for fertilization in wheat crop and it was reported to be 536.82 in cotton fertilization. The average soil contamination (SC) risk was higher in cotton fertilization (2.79) than in wheat fertilization (2.47) and the maximum value was reported in Muktsar district for cotton fertilization (3.11). The wheat fertilization practice in the study area threats only nitrate pollution whereas the fertilization in cotton has associated risks of both nitrate and phosphate pollution in the study area.

Key Words: Fertilization Unsuitability Index, Soil Contamination, Nutrient Imbalance, GIS

The crop productivity is dependent on the availability of sufficient nutrients and this nutritional demand is met by means of mineral fertilizers which are applied to soil at different stages of plant growth. The recommendation level of fertilizers is crop and region specific based on the crop variety and inherent nutrient supplying capacity of the soil in which crop is being produced. According to Fertiliser Association of India, six crops *viz.* rice, wheat, cotton, sugar cane, rapeseed-mustard, and potato consume more than two-thirds of the fertilizer. According to one estimate, 14 million tons of nitrogen is added annually to Indian soils in the form of mineral fertilizers. The fertilizer consumption in Indian agriculture increased from 0.13 Mt in 1955-56 to 14.3 Mt in 1996-97 (Rao and Srivastava, 1998).The under dosage of fertilizer, will trigger the heath and vigour of plants and on the other hand the overdose will lead to nutrient leaching and environmental pollution and definitely affecting the economy of agriculture business. The uncontrolled manner of fertilization to crops exhibit a great environmental threat as excess amounts of nutrients is flowed down into water bodies and triggers growth of unwanted plants and algae. With inefficient use of fertilizers, significant amounts of nutrients escape into the air, or seep into the soil and underground water, which in turn result in a host of environmental and human health problems, from climate change and dead zones in the oceans to cancer and reproductive risks (Galloway *et al*., 2008). The over fertilization with nitrogenous fertilizers poses risk of methemoglobinemia, or blue baby syndrome associated with nitrate pollution and on the other hand over fertilization with phosphate fertilizer poses the risk of eutrophication i.e. the growth of unwanted algae in water bodies increasing biological oxygen demand (BOD). According to a review by the Food and Agricultural Organization (FAO) in the 1990s, about half of the cultivable soils in India were degraded, which is the highest percentage in the Asian-Pacific region (Scherr, 1999). The judicious use of fertilizers keeping in mind application timing, weather conditions, proximity to crop growth etc., will not only reduce the amount of N required but also thereby the loss of N to air, soil and water from the current 60 per cent (possibly as high as 80 per cent) to an average of 30 per cent as in much of Europe and North America (Ju *et al*., 2009). Therefore, it is necessary to have a check on the fertilization at field level to eliminate the chances of environmental contamination on later stages. Developments in information and communication technology have given rise to frontier technologies like remote sensing, geographic information systems (GIS) and global positioning system (GPS) and are

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indispensable tool for natural resource management. In this study the fertilisation trend to meet the requirement of primary nutrients is studied in cotton growing belt of Punjab and results are represented in thematic maps using GIS.

MATERIAL AND METHODS

The cotton producing districts of Punjab namely Bathinda and Muktsar situated between 29.78° N to 30.67° 'N of Latitude and 74.25° E to 75.38° E of Longitude and with total geographical area 5,946.00 km was selected for studying fertilizer usage trends. The farmers in the study area produce two main crops in a cropping year predominantly cotton (*Gossypium hirsutum* L) in summer and wheat (*Triticum aestivum*) during winter. The nutritional demand of crops is met by application of urea and diammonium phosphate for the supply of nitrogen and phosphorus, respectively and murate of potash (Potassium chloride) for the potassium supply.

A sample size of 138 villages from two districts namely Bathinda and Muktsar of Punjab state in India was randomly selected from the cotton growing region of study area and survey questionnaire was distributed through the channel of village scouts for the collection fertilization data from the farmers. The queries regarding various farming activities including fertilizer usage were made directly with the farmers of the study area during the cotton cropping season of 2010. The data collected was converted to geospatial format using Arc GIS v9.1 and digital maps were generated to study fertilization pattern in cotton and successive wheat crop in the study area. The village boundaries obtained from Survey of India were used to display the results in geo-spatial format. The statistical interpolation was performed in Arc GIS v9.1 software using Inverse distance weighted technique for spatial analysis. The descriptive statistical analysis was performed using data analysis add-in in Excel module of Microsoft Office 2010.

The recommended doses of fertilisers have also been defined for all crops by PAU, Ludhiana based on crop varieties, soil properties and weather conditions (Table 1). The overuse of applied fertilisers was calculated based on recommended fertiliser dose (RDF) for the study area (Anonymous, 2010) and studied for urea and DAP application in both cotton and wheat crops.

The overuse of fertilizer application was calculated as percentage of urea and DAP application above recommended level.

$$\% \text{ Overdose of fertilizer} = \frac{[(\text{Applied dose(kg/acre)} - \text{Recommended fertilizer dose (kg/acre)}]}{\text{Recommended fertilizer dose (kg/acre)}} \times 100$$

RESULTS AND DISCUSSION

General Fertilization Pattern

The spatial representation of fertilization trend showed that the majority of villages in the study area were comparatively over fertilized with the nitrogen in both cotton and wheat (Fig 1 and 2). Also phosphorus over fertilization was reported in cotton cultivation but in wheat recommendation DAP at the rate of 55kg per acre was followed by the majority of farmers in the study area. Further the incidence of over fertilization was comparatively higher in Bathinda as comparison to the Muktsar district and the extent of over fertilization was higher for urea application than DAP application for both the crops in the study area. The study of urea application pattern showed that majority of farmers had applied more than 100% of excess urea in their fields in both Bathinda and Muktsar districts and most farmers have applied 50 per cent excess DAP in cotton crop. The availability of DAP fertilizer in Punjab in the 50kg bags may be reason of DAP over fertilization in cotton which requires it at the rate of 27 kg per acre.

The over fertilization in both crops with urea may be attributed to higher subsidies on nitrogen fertilizers in India thus shifting the balance of fertilizer use in favour of N and against P and K (Chand and Pandey, 2008). In India the use of urea is a common practice, the soil degradation associated with this practice gives an early warning about the unsustainability of the current system (Masto *et al.*, 2008). Apart from nutrient imbalances, it also negatively affects the physical and biological properties of the soils as microbial biomass, enzymatic activity and water-holding capacity are all drastically reduced under nitrogen fertilizer practices (Masto *et al.*, 2008; Kang *et al.*, 2005). Another common detrimental effect of the excess use of nitrogen fertiliser on soil health is acidification, and microorganisms which are crucial for natural nutrient cycling (Darilek *et al.*, 2009; Kibblewhite *et al.*, 2008).

Table 1. Recommended fertilizer dose of major fertilizers in cotton and wheat in Punjab

Crop/variety	Urea (kg/acre)	Diammonium Phosphate (kg/acre)	Muriate of Potash (kg/acre)
Cotton-Bt and Hybrids	120	27	20
Wheat-PBW 343,502, 550	90	55	20

Source: Anonymous, 2010

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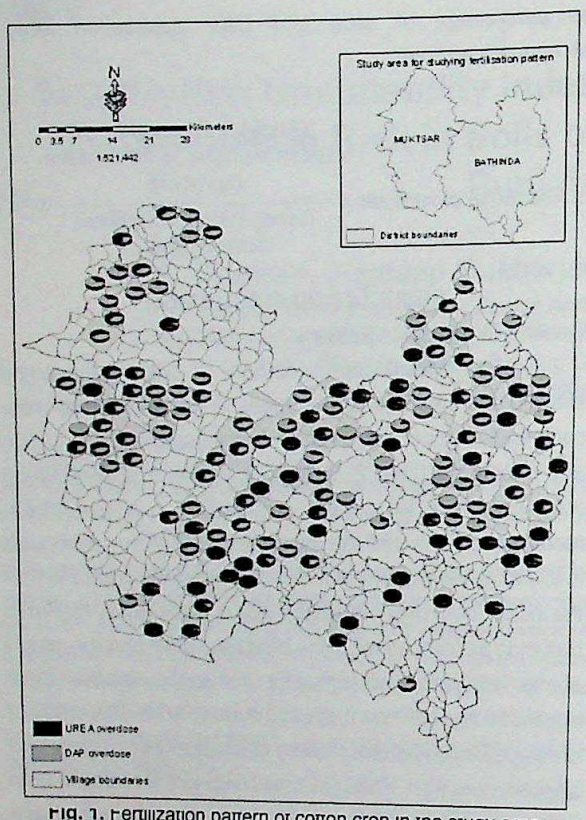

Fig. 1. Fertilization pattern of cotton crop in the study area

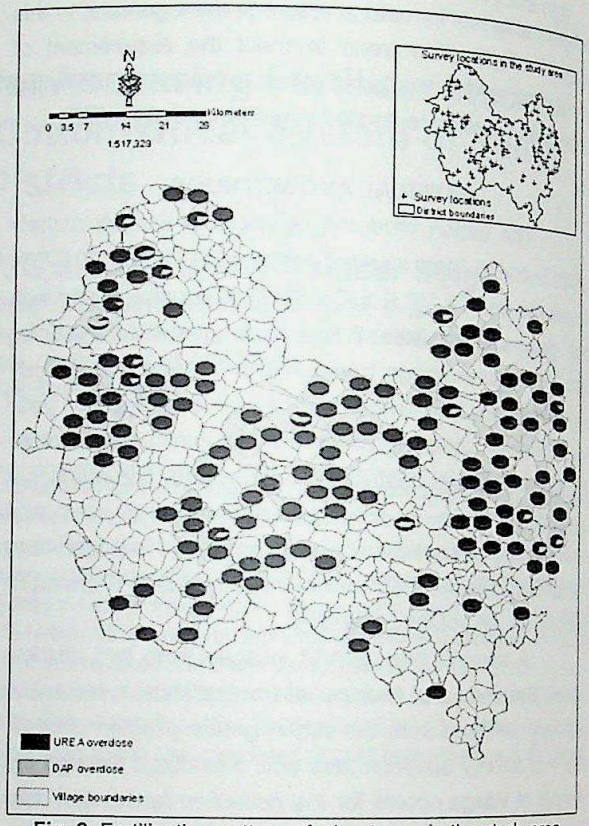

Fig. 2. Fertilization pattern of wheat crop in the study area

In addition to widespread environmental damage, studies carried out under different cropping systems have categorically shown that stretching of synthetic fertilizer application to 150 per cent of recommended rate does not result in significant increments in crop yields (Mandal 2006).On contrast addition of organic matter, commonly in the form of farm-yard manure, is very effective in improving soil quality and yields (Yadav *et al.*, 2000; Dwivedi *et al.*, 2003; Singh *et al.*, 2005; Mandal *et al.*, 2006; 2007).

Development of Fertilization Unsuitability Index

It was found that the urea and DAP were the frequently over used fertilisers and muriate of potash (potassium chloride) was used at recommended levels and not considered for derivation of fertiliser unsuitability index (FUI). Moreover, unlike nitrogen and phosphate, potash has no known role in soil and ground water contamination (Syers, 1997).A index defining the magnitude of variation of applied fertilizers over the basal recommended fertilizer dose was derived based on the following hypothesis:

I. Fertilization unsuitability index for fertilization at recommended dose is zero and it represents perfect fertilization for a particular crop and soil type.
II. It is combined measure of adverse affects it exert on surrounding environment and crop nutrition in the form of soilcontamination and nutrition imbalance respectively. For mathematical convenience it is expressed as quadratic mean of Soilcontamination factor (SC) and Nutritional imbalance (NI) factor.
III. The excess of mineral nutrients (nitrogen & phosphorus) released to the soil depends on fertilizer composition and are the potential pollutants and are ultimate risk to the environment in every possible way.

Based on above assumption, the Fertilization Unsuitability Index (FUI) for combination of fertilizer applications in a crop originating at source per unit area is given as:

$$FUI = \pm F\sqrt{[(SC)^2+(NI)^2]}/2 \text{(kg/acre)}$$

$$SC = \sum x_i/X_i - n \text{ and } NI = \sum x_i/x_{i+1} - C$$

where x_i is amount of fertilizer applied in kg/acre against recommended dose of X_i, n is total number of fertilizers applied in a crop,F is fertilizer specific factor (based on nutrient composition), C is crop specific factor (equal to summation of ratios of recommended doses of successive fertilizers).

The value of FUI is positive for over fertilization and negative for under fertilization (Fig 3).

The above formula is simplified for dual fertilization which is common practice in the study area where urea (46% N) and diammonium phosphate (46% P_2O_5 and 18%N) fertilizersare applied in cotton and wheat crops and FUI index

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is expressed as:

$FUI_c = \pm(0.46x + 0.64y)\sqrt{[(x/120 + y/27 - 2)^2 + (x/y - 4.4)^2]/2}$

$FUI_w = \pm(0.46x + 0.64y)\sqrt{[(x/90 + y/55 - 2)^2 + (x/y - 1.64)^2]/2}$

Where FUI_c , FUI_w are fertilization unsuitability indices for cotton and wheat crops and x, y are the actual amounts of urea and diammonium phosphate applications by the farmers in the fields.

The calculated value soil contamination reflects the relative degree of over fertilization and resulting threat in the form of soil contamination owing to the excess of nutrients released to the surface waters. The positive values of SC represents over fertilization whereas negative value shows fertilizer is applied at lower levels than recommended for a crop. The calculated value of NI indicates which fertilizer is playing dominant role in soil contamination, if it is positive it designates nitrogen pollution and if it is negative it shows phosphate pollution is in action (Fig 3).The calculated values of SC with proportional increment in the applied urea and DAP in a crop for sake of reference scale is given in Table 2.

Spatial Representation of Fertilization Indices for the Study Area

The study of the fertilization trends in the study area,

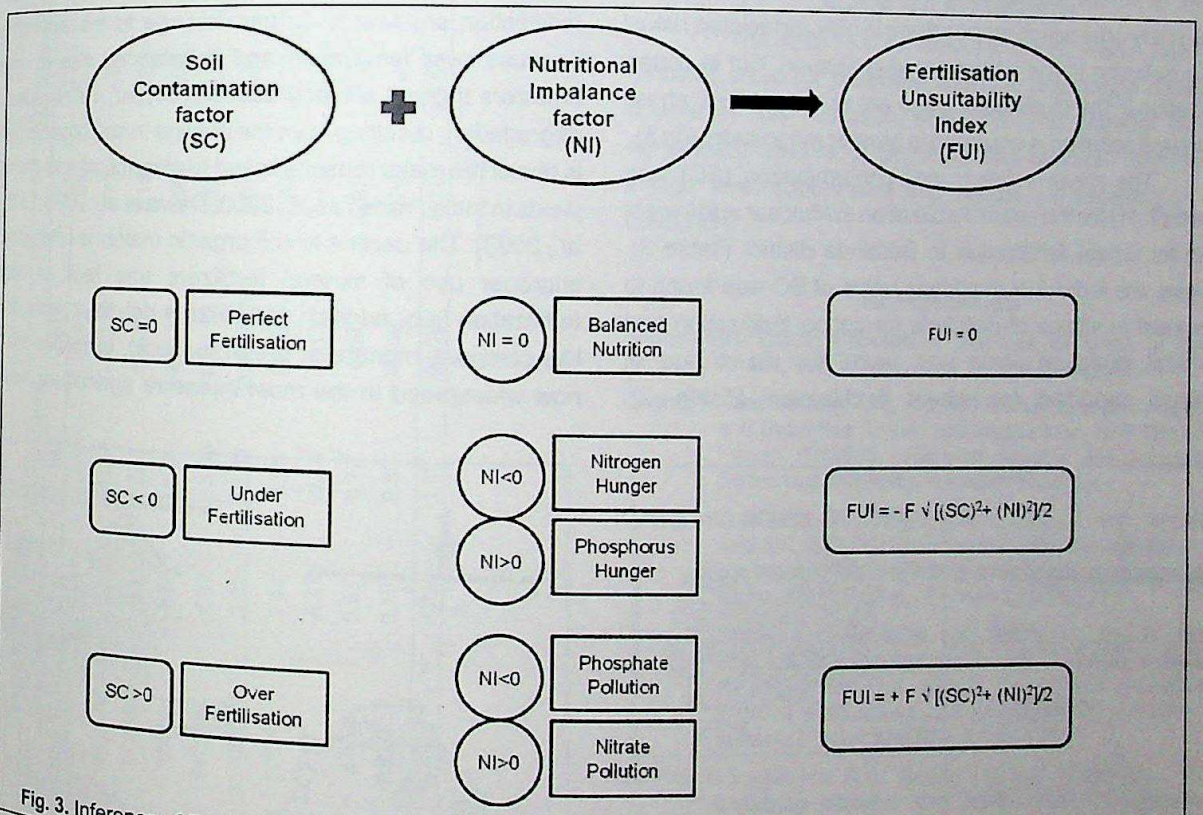

Fig. 3. Inference of Fertilization Unsuitability Index for fertilizer (urea and diammonium phosphate) application in a crop

Table 2. Calculated values of soil contamination factor (SC) for incremental doses of urea and DAP fertilization

	Percentage of higher dose of Urea over recommended basal dose									
	5	10	25	50	75	100	150	250	350	500
5	0.1	0.2	0.3	0.6	0.8	1.1	1.6	2.6	3.6	5.1
10	0.2	0.2	0.4	0.6	0.9	1.1	1.6	2.6	3.6	5.1
25	0.3	0.4	0.5	0.8	1.0	1.3	1.8	2.8	3.8	5.3
50	0.6	0.6	0.8	1.0	1.3	1.5	2.0	3.0	4.0	5.5
75	0.8	0.9	1.0	1.3	1.5	1.8	2.3	3.3	4.3	5.8
100	1.1	1.1	1.3	1.5	1.8	2.0	2.5	3.5	4.5	6.0
150	1.6	1.6	1.8	2.0	2.3	2.5	3.0	4.0	5.0	6.5
250	2.6	2.6	2.8	3.0	3.3	3.5	4.0	5.0	6.0	7.5
350	3.6	3.6	3.8	4.0	4.3	4.5	5.0	6.0	7.0	8.5
500	5.1	5.1	5.3	5.5	5.8	6.0	6.5	7.5	8.5	10.0

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the calculated values of soil contamination at selected locations is interpolated using Arc GIS platform to present a whole picture of the study area. This approach helped in the identification of spatial location of the problem area where the problem of over fertilization is more intense. The results showed that in cotton fertilization, the SC values generally ranged between 1-2 in Bathinda district and 2-4 in Muktsar district which means combined adverse affect of urea and DAP on soil is more pronounced in Muktsar district (Fig 3) . Similarly for wheat fertilization in the study area, the values of SC ranged between 1-2 for most area of Bathinda and 2-4 for maximum geographical area falling under Muktsar district (Fig 4). In wheat fertilization, the value of NI is positive for whole study area which means there is only associated risk of nitrate pollution in the wheat growing season. But in cotton fertilization in the study area, there are some patches where phosphate pollution is occurring in greater magnitude (Fig 5).

The mean value of soil contamination (SC) was highest (3.11) for the cotton fertilization in Muktsar and lowest (2.19) for wheat fertilization in Bathinda district (Table 3). Whereas the individual maximum value of SC was found to be highest in village of Bathinda for cotton fertilization and individual minimum value was found for the village of Bathinda reported for wheat fertilization (Table 2). Calculated values of soil contamination factor (SC) for incremental doses of urea and DAP fertilization above RFD percentage higher dose of diammonium phosphate over recommended basal dose.

The calculated values of fertilization unsuitability index (FUI) showed the maximum range and magnitude for cotton festination in Bathinda followed by wheat fertilization in Muktsar. While the minimum FUI was reported for wheat fertilization in Bathinda district in the study area. The mean value of FUI was highest (544.52) for wheat cultivation in Muktsar and lowest (438.18) for wheat cultivation in Bathinda (Table 3). The above results demonstrates a high degree of over fertilization in the study area and need to check on the fertilization practice to further damage to the environment because over fertilization and imbalanced use of mineral fertilizers triggers soil degradation (Scherr, 1999). Also, soil degradation, resulting from the decline in soil organic matter, is one of the major reasons linked to stagnation and decline in yields in India (Yadav *et al*., 2000; Dawe *et al*., 2003; Ladha *et al*., 2003). The decline in soil organic matter is related to the improper use of mineral fertilizers and lack of organic fertilization (e.g. addition of fertilizers rich in organic matter, like compost, manure or green manure), practices that are now widespread in the most intensive agriculture areas in

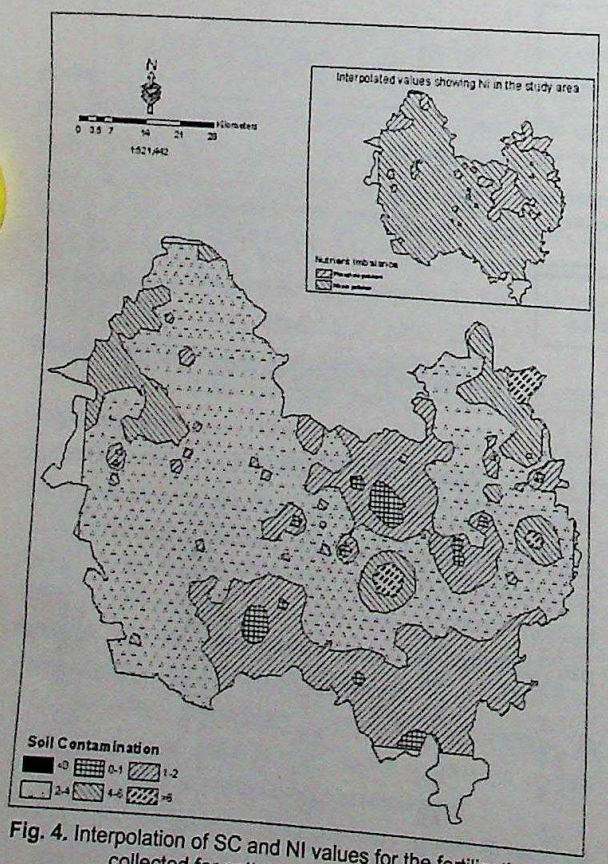

Fig. 4. Interpolation of SC and NI values for the fertilization data collected for cotton crop in the study area

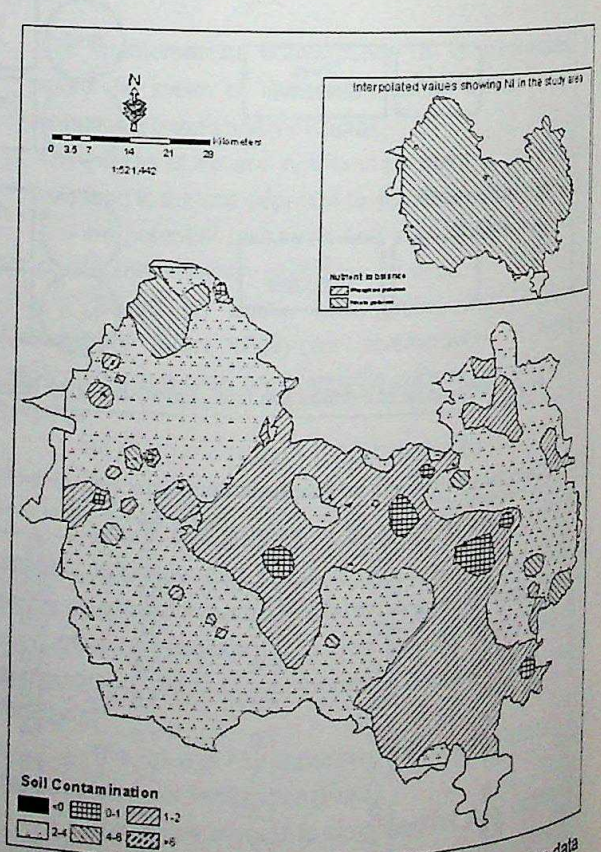

Fig. 5. Interpolation of SC and NI values for the fertilization data collected for wheat crop in the study area

Table 3. *Descriptive statistical measures calculated for the fertilization based indices for cotton and wheat fertilization in the study area*

Statistical measure	Cotton crop fertilization		Wheat crop fertilization	
	Bathinda district	Muktsar district	Bathinda district	Muktsar district

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Table 3. Descriptive statistical measures calculated for the fertilization based indices for cotton and wheat fertilization in the study area

Statistical measure	Cotton crop fertilization						Wheat crop fertilization					
	Bathinda district			Muktsar district			Bathinda district			Muktsar district		
	SC	NI	FUI	SC	NI	FUI	SC	NI	FUI	SC	NI	FUI
Minimum	-0.06	-3.77	-36.12	0.69	-2.44	98.02	0.02	-0.39	14.06	0.02	-0.64	14.06
Maximum	10.78	15.56	3439.72	6.70	11.16	1383.38	5.73	9.61	1241.55	7.21	10.36	1811.83
Mean	2.47	2.49	517.59	3.11	2.57	536.82	2.19	3.80	438.18	2.75	4.04	544.52
Median	1.70	1.56	324.55	2.95	1.56	448.79	1.98	3.36	331.31	2.58	3.92	513.62
Range	10.83	19.33	3475.85	6.02	13.60	1285.36	5.71	10.00	1227.49	7.19	11.00	1797.77
Sample Variance	4.35	20.95	357093.47	2.02	13.38	118749.76	2.03	5.28	115201.89	2.51	5.60	140587.16
Standard Deviation	2.08	4.58	597.57	1.42	3.66	344.60	1.43	2.30	339.41	1.58	2.37	374.95
Kurtosis	5.31	0.25	7.57	-0.37	-0.45	-0.13	-0.13	-0.69	-0.72	0.44	-0.44	1.16
Skewness	2.05	0.87	2.53	0.53	0.72	0.69	0.67	0.43	0.77	0.66	0.27	0.90
Standard Error	0.23	0.50	65.20	0.19	0.50	46.89	0.16	0.25	37.03	0.22	0.32	51.02
Confidence Level (95.0%)	0.45	0.99	129.68	0.39	1.00	94.06	0.31	0.50	73.66	0.43	0.65	102.34

SC: Soil Contamination Factor
FUI: Fertilization Unsuitability Index
NI: Nutrient Imbalance Index

India (Masto *et al.*, 2008; Singh *et al.*, 2005).

The overuse of mineral fertilisers has also been linked to soil degradation problems such as soil acidification and alkalization, as well as deterioration of the soil's physical properties, such as infiltration, soil aeration, soil structure and bulk density. However, since much of this N is used inefficiently, significant amounts escape into the air, or seep into the soil and underground water, which in turn result in a host of environmental and human health problems, from climate change and dead zones in the oceans to cancer and reproductive risks (Galloway *et al.*, 2008).

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Potassium Fixation Isotherms and Factors Affecting Potassium Fixation in Rainfed Soils of District Ganderbal, J&K

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Abstract: K fixation (KF) isotherms and factors affecting KF were studied in rainfed maize growing soils of North Kashmir for understanding and measuring the inherent potential of soils to deliver K to crops and factors determining K availability. KF isotherms were constructed by equilibrating 5g soil samples with eight levels (0-200µg mL^{-1}) of K contained in 10ml of KCl solution. Factors affecting soil KF were then extracted by factor analysis and stepwise regression. At K addition treatments of 1 and 200µg K mL^{-1} contained in 10ml of KCl solution, the fixed amounts of K varied from 130 to 210 per cent and 16.35 to 36.3 per cent of added K respectively. The fixation data were fitted to Freundlich, Langmuir and Temkin fixation equations. Freundlich equation explained K fixation behavior better than the either two equations as evidenced by higher R^2 (0.90-0.99). Magnitude of soil KF capacity was found highest in Silty clay (S7) and lowest in Sandy loam (S6). K fixation capacity was significantly correlated with CEC and clay content. KF capacity of soils was affected by two components extracted by the method of PCA: the first including soil available K (Av. K), exchangeable K (Ex. K), OC and EC and the second including CEC and clay contents. KF rate was mainly affected by CEC and Av. K with lower added K concentration (from 1-20µg mL^{-1}) and by clay and OC with higher added K concentration (from 60-200µg mL^{-1}).

Key words: Potassium Fixation Rate, Potassium Fixation Capacity, Freundlich, Langmuir, Temkin Equation

Potassium (K) is one of the three major nutrients required for plant growth and reproduction and a significant quantity of K is removed by maize crop (White, 2003). The availability of K is influenced by soil physico-chemical and biological properties (HuiMin *et al.*, 2009). Transformation of available K forms into unavailable ones (K-fixation) influences the K availability and the degree of fertilizer K uptake by plants. Consequently, understanding the mechanism that involve fixation of K in soil is of particular agronomic and practical interest (Simonsson *et al.*, 2009). A rapid method for measuring K fixation could help clarify relationship with other soil properties (Murashkina *et al.*, 2007).

The K fixation in soil is quite complex and may not be explained by simple and single reactions. To visualize the K fixation in soil several equations or fixation isotherms have been developed. Their use allows summarizing results, reducing the sorption data to comparable values. Among isotherm adsorption equations, Langmuir, Freundlich and Temkin equations are the most used for soil characterization and research purposes however the conformity of the equations and their constants still remains in discussion (Taylor *et al.*, 1996). Langmuir and Freundlich fixation isotherms are mostly employed for understanding the relationship between the quantities of K fixed per unit soil weight and the concentration of K in solution. The Freundlich equation is the oldest fixation equation in the literature on soils, first used by Russell and Prescott in 1916. It is an empirical equation and corresponds to an equation of fixation in which the affinity term decreases exponentially as the amount of fixation increases. Over a limited range of concentration, Freundlich equation often describes the K fixation well (Hannan *et al.*, 2011). According to the Freundlich equation, energy of fixation decreases as the amount of fixation increases.

The K fixation in North Kashmir soils specifically in rainfed Karewas (Lacustrine deposits) where wetting and drying play a predominant role in K fixation having soil depth ranging from 10-30cm with slope in the range of 8-15% is not well documented as intensive investigations in this regard had not been undertaken so far. The present study was therefore, conducted to elucidate the K fixation in rainfed soils.

MATERIAL AND METHODS

Soil Sampling and Experimental Site: The study area is in the North of Kashmir valley, Ganderbal District, India. The cultivated area falls in the rainfed zone dominated by maize cropping. Ten surface soil samples (0-20cm) in triplicate of low (Babaweyl, Satran, Doon and Mamar), mid (Chatergul, Wangat and Sumbal) and high (Ghund, Kulan

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and Gagangir) altitude zones with altitude range of <1600, 1700-1800 and >1900m masl respectively were collected. The samples inherit wider range of soil characteristics like texture, pH, clay contents, $CaCO_3$ and organic matter (Table 1). The soil samples were air-dried and ground to pass through 2mm sieve before use.

Measurement

Soil Analysis: The pH was determined by 1:2.5 soil-water suspension by a glass electrode, EC with the help of solu bridge conductivity meter at 25° C (Jackson, 1967) and CEC by ammonium acetate or ammonium chloride-ammonium acetate method (Lu, 1999). Particle size distribution was determined by the sedimentation procedure using the pipette method after dispersing the soil with sodium hexametaphosphate (Gee and Bauder 1986). The total $CaCO_3$ in soil expressed as the calcium carbonate equivalent was determined by a rapid titration method (Rayment and Higginson 1992). Organic matter was determined by wet digestion (Nelson and Sommers 1996). Available potassium was extracted with normal neutral ammonium acetate (Pratt, 1982). Equilibrium K concentration with distilled water (Jackson, 1967) and Exchangeable potassium was obtained from the difference between available potassium and water soluble potassium (Dhillon *et al.*, 1985).

Potassium Fixation: The K fixation capacity was calculated by using Huang and Jin (1996) procedure. Surface samples (5g) were taken and equilibrated in 50mL plastic bottles for 72 hours at 25±1°C after adding eight rates of 0, 1, 5, 10, 20, 60, 100 and 200 µg K mL^{-1} in 10ml of KCl solution and then analyzed for K in 1mol/L NH_4OAc extract (pH 7) with a flame photometer.

The assessment of K fixation capacity was calculated as follows (Huang and Jin, 1996):

K fixation capacity (µg g^{-1}) = added K - (NH_4OAc extractable K- original soil K)

K fixation rate (%) = (K fixation capacity × 100)/ added K

The K fixation data were fitted into following fixation equations:

Langmuir Fixation Equation:

$$C/(x/m) = 1/kb + C/b$$

Where C is the equilibrium solution K concentration (µg g^{-1}), x/m is the mass of K adsorbed per unit mass of soil (µg g^{-1}), *k* is a constant related to bonding energy of K to the soil, and 'b' is the maximum K fixation capacity of the soil.

Freundlich Fixation Equation:

$$x/m = a\,C^{1/n}$$

By rearranging

$$\log (x/m) = \log a + 1/n \log C = \log a + b \log C$$

Where x/m is the mass of K adsorbed per unit mass of soil (µg g^{-1}), C is the equilibrium solution K concentration (µg g^{-1}), 'a' and 'b' are constants. The values of 'a' and 'b' are obtained from the intercept and slope, respectively.

Temkin Fixation Equation:

$$x/m = a + b \ln C$$

Where x/m is the mass of K adsorbed per unit mass of soil (µg g^{-1}), C is equilibrium solution K concentration (µg g^{-1}), 'a' and 'b' are constants. The values of 'a' and 'b' are obtained from the intercept (a) and the slope (b), respectively. The K buffering capacity (PBC^K) was interpolated from the K sorption isotherms by determining the slope of the lower linear portion of the curve. The necessary statistical analysis of the data were done using MS Excel and XlStat software programme.

RESULTS AND DISCUSSION

Potassium Fixation: The soils differed in their K

Table 1. Physico-chemical properties of maize growing soils of District Ganderbal

Site	Location	Altitude (masl)	pH (1:2.5)	EC (dSm^{-1})	Organic carbon	$CaCO_3$	C E C cmol (P^+) Kg^{-1}	Coarse sand	Fine sand	Silt	Clay	Av. K [$cmol_c$ Kg^{-1}]	Ex. K [$cmol_c$ Kg^{-1}]	PBC^K ($cmol_c$ kg^{-1})/ (mol L^{-1})$^{1/2}$
					Per cent			Per cent						
S_1	Babaweyl	1700	7.1	0.35	2.08	0.50	15.50	5.69	45.24	21.33	26.30	0.519	0.408	31.36
S_2	Satran	1780	7.1	0.38	2.45	0.50	16.23	10.53	43.21	31.32	13.93	0.532	0.376	29.63
S_3	Doon	1800	7.7	0.29	1.07	0.63	17.50	0.63	1.31	60.12	37.00	0.237	0.216	34.72
S_4	Mamar	1820	7.8	0.44	0.90	0.55	15.36	23.43	27.25	18.23	30.93	0.132	0.119	31.08
S_5	Chatergul	1900	7.4	0.20	1.18	0.10	17.70	11.25	39.08	16.21	32.21	0.207	0.190	26.36
S_6	Wangat	1920	6.8	0.43	2.06	0.14	17.70	20.43	47.49	12.33	18.92	0.427	0.389	33.69
S_7	Sumbal	1940	6.2	0.45	3.00	0.64	17.96	9.65	13.55	26.25	50.30	0.895	0.818	37.62
S_8	Ghund	2020	6.4	0.40	2.75	0.53	17.85	6.00	14.32	40.20	38.40	0.701	0.523	35.01
S_9	Kulan	2100	7.6	0.42	2.85	0.21	17.95	1.42	18.20	40.33	39.92	0.846	0.750	36.79
S_{10}	Gagangir	2270	7.5	0.21	1.98	0.38	17.40	22.84	40.52	18.23	18.12	0.250	0.233	21.95
	Mean		7.2	0.37	2.03	0.35	17.11	11.19	29.02	28.46	30.60	0.464	0.412	31.82

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fixation behavior (Table 2). Irrespective of soil type and clay content the amount of K fixed increased with the increasing K additions (Figure 1). Jafari and Baghernejad (2007) and Srinivasarao *et al.* (2007) also reported that fixation of potassium increased with increasing concentration of added K in solution. For the initial added solution concentration of K (1 μg mL^{-1}), K fixed ranged from 130 to 210% and for the highest added solution concentration of K (200 μ g mL^{-1}) 16.3 to 36.3%. The NH_4AOc extractable K [C] ranged from 0.25 to 0.70 μg mL^{-1} for 1 μg mL^{-1} of added K and from 164 to 184 g mL^{-1} for 200 μg mL^{-1} of added K (Table 2). The highest mean K fixation capacity (KFC) of 26.4μg g^{-1} soil was observed in Silty clay (S_7) soil and lowest value of 13.4μg g^{-1} soil was observed in Sandy loam (S_6) soil. The mean K fixation rate (KFR) ranged from 51.56% to 84.60% which accounts for Loam (S_4) soil and Silty clay (S_7) soil respectively (Table 2). The maximum K fixation rate of 210% at lowest concentration of treated K (1μg mL^{-1}) and 36.3% at highest concentration of added K (200g mL^{-1}) with a mean value of 28.04 was observed for Silty clay (S_7) soil. Overall the KFC and KFR of soils ranged from 1.48μg g^{-1} and 157.4% at 1g mL^{-1} of added K to 62.49μg g^{-1} and 28.04% at 200g mL^{-1} of added K respectively (Table 2).

The K buffering capacity (PBC^K) ranged from 21.95 to 37.62 ($cmol_c$ Kg^{-1})/(mol L^{-1})$^{1/2}$. In general, the higher PBC^K are for the soils containing large amounts of clay and indicative of the continuing availability of adequate K over a long period of cropping where as low buffering indicates the need for frequent fertilization (Pal *et al.*, 1999).

Applicability of Different Kinetic Equationsto Describe Potassium Fixation

The data on potassium fixation obtained for different soils at different concentrations of treated K were fitted to various kinetic equations viz., Langmuir, Freundlich and Temkin equation for testing their applicability using least square regression analysis. The values of coefficient of determination (R^2) for different potassium kinetic equations (Table 3) indicate that potassium sorption isotherms (Figure 2)were well described by the Freundlich equation used in this study for all the soils based on the highest value of R^2. The equation gave a better fit as it assumes unlimited fixation sites having heterogeneous surfaces which correlate better with the physico-chemical factors of the soils.

The values of the Freundlich constants 'a' and 'b' were determined from the plots between logx/m and logC. The Freundlich constant 'a' was obtained from the intercept at zero equilibrium concentration and 'b' from the slope of the plot. 'a' and 'b' provide the estimates of fixation capacity and intensity of fixation respectively. The values of 'b' also

Table 2. Amount of K fixed (μg g^{-1}) in different soils treated with different concentrations of K

Location	Added Potassium (μg mL^{-1})																					
	1			5			10			20			60			100			200			Mean	
	[C]*	[x/m]**	(%)***	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)	[C]	[x/m]	(%)
S_1	0.60	1.3	130.0	3.0	4.5	90.0	7.6	5.3	53.0	16	8.5	42.5	48	24.5	40.8	80	40.5	40.3	167	66.5	33.3	46.0	21.6	61.4
S_2	0.25	1.7	174.0	2.5	5.2	104.8	5.6	9.0	90.4	15.5	9.2	46.2	48	24.2	40.3	81	38.2	38.2	167	40.24	20.1	47.5	18.3	73.5
S_3	0.50	1.4	140.0	2.5	5.4	108.0	6.5	7.4	74.0	14	12.4	62.0	45	30.4	50.4	78	44.4	44.3	165	70.4	35 2	44.5	24.5	73.5
S_4	0.55	1.3	130.0	4.0	2.4	48.0	8.0	4.4	44.0	16	8.4	42.0	49	22.4	37.2	84	32.4	32.3	173	54.4	27.2	47.8	18.0	51.6
S_5	0.45	1.7	170.0	3.0	4.6	92.0	8.5	3.6	36.0	17	6.6	33.0	52	16.6	27.5	88	24.6	24.5	182	36.6	18.3	50.1	13.6	57.4
S_6	0.70	1.3	130.0	2.8	5.1	102.0	6.0	8.7	87.0	17	6.7	33.5	52	16.7	27.7	89	22.7	22.6	184	32.7	16.3	50.2	13.4	60.0
S_7	0.25	2.1	210.0	3.0	4.6	92.0	6.5	7.6	76.0	13	14.6	73.0	44	32.6	54.3	75	50.6	50.6	164	72.6	36.3	43.7	26.4	84.6
S_8	0.50	1.4	140.0	2.3	5.8	116.0	7.0	6.4	64.0	14	12.4	62.0	43	34.4	57.3	77	46.4	46.3	164	72.4	36.2	44..0	25.6	74.6
S_9	0.50	1.8	180.0	3.5	3.8	76.0	7.0	6.8	68.0	14	12.8	64.0	43	34.8	58.0	73	54.8	54.0	152	64.8	32.4	41.8	25.6	76.2
S_{10}	0.30	1.7	170.0	2.2	5.9	118.0	8.0	4.3	43.0	16	8.3	41.5	46	28.3	47.2	84	32.3	32.3	172	50.3	25.2	47.0	18.7	68.2
Mean	0.46	1.6	157.4	2.8	4.7	92.7	7.1	6.4	63.5	15.3	9.9	49.9	47.0	26.5	44.1	80.9	38.7	38.5	169.0	62.5	28.0	46.8	20.6	68.1

*Equilibrium concentration (μg mL^{-1}); **Amount of added K fixed or K fixation capacity (μg g^{-1}) and ***Per cent of added K fixed or K fixation rate

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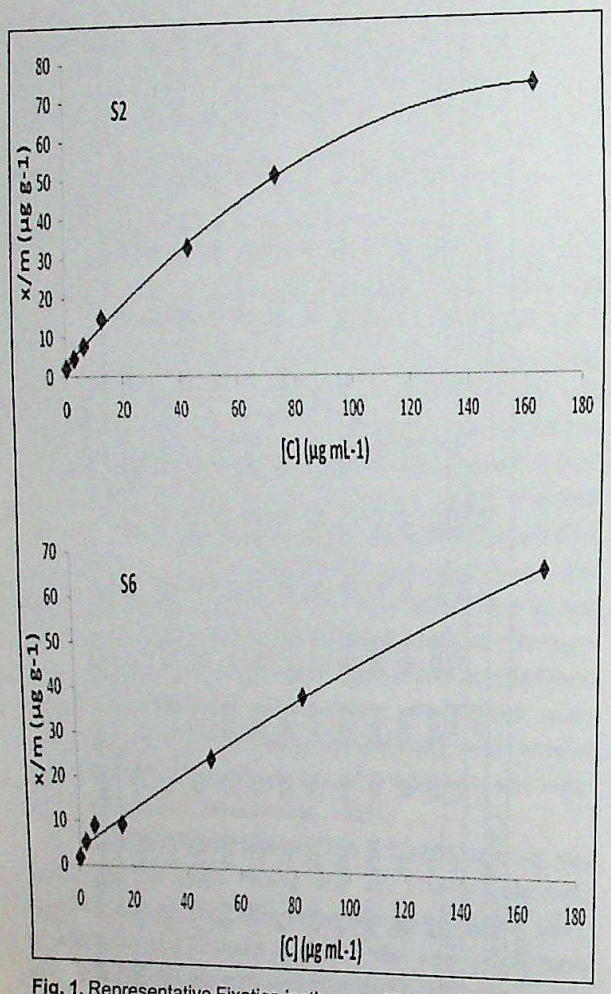

Fig. 1. Representative Fixation isotherms of S_2 and S_6 soils of maize growing soils of North Kashmir

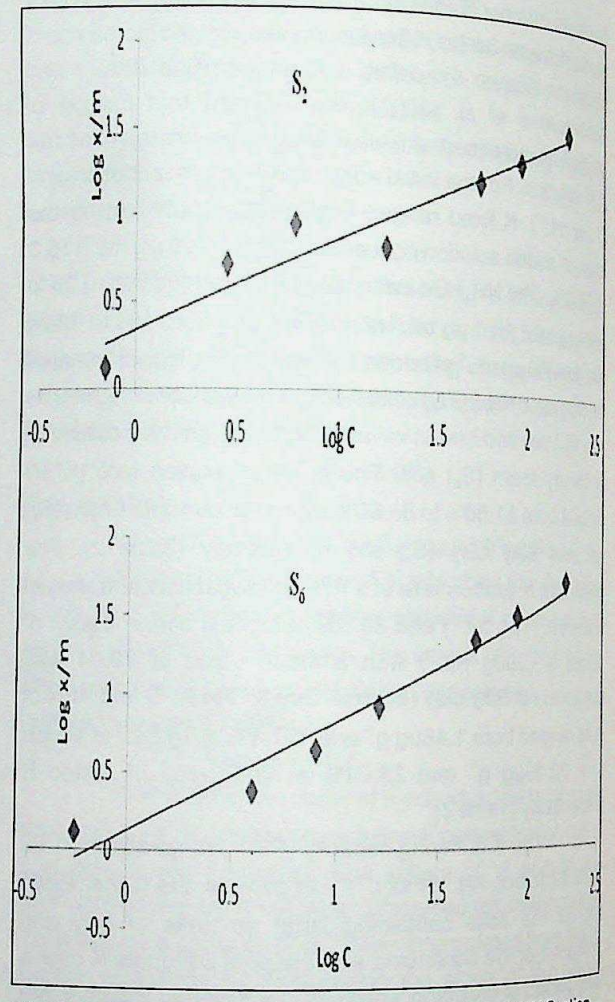

Fig. 2. Representative Freundlich fixation isotherms for K fixation by maize growing (S_2 and S_6) soils of North Kashmir

indicate the degree of non-linearity between solution concentration and fixation.

A plot of potassium fixed against equilibrium potassium concentration on a log scale gave linear relationship in all soils (Fig. 2). The Freundlich 'a' values ranged widely among the soils. The value was maximum of 3.38µg g^{-1} was found Silty Clay (S_7) soil which may be due to high organic carbon, CEC, clay content and Av. K. The maximum value of 'b' (2.02) was obtained in Silty loam (S_2) soil and minimum value (1.44) was obtained in Clay loam (S_1) soil and Loam (S_4) soil.

Effect of Soil Properties on Potassium Fixation: Factor Analysis

The potassium fixation capacity differences among soils or treatments are related to the differences in soil available K (Av. K), exchangeable potassium (Ex. K), CEC, clay content, organic matter and electrical conductivity (EC) (Table 1). The data was further analyzed by the Varimax with Kaiser Normalization method to know how these factors affect K fixation capacity (Table 5). By the method of principle component analysis two components were extracted. Four factors, including Av. K, Ex. K, OC and EC, had a large positive loading (0.702-0.922) on the first component, and a small positive loading (0.313-0.409) or negative loading (-0.156) on the second component. The other two factors, including CEC and Clay, in contrast, had a small positive loading (0.072-0.352) on the first component, and a large positive loading (0.757-0.997) on the second component. The two components had great communalities (0.688—0.982) for all the six factors. Therefore, the first component included soil Av. K, Ex. K, OC and EC, and the second component included CEC and clay contents.

Stepwise Regression Analysis: Relationships between K Fixation Rate and Factors Affecting K Fixation

The data between K fixation rates of rainfed maize growing soils and factors affecting K fixation capacity showed

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a significant correlation upon stepwise regression analysis (Table 5). The K fixation rate was significantly correlated with Av. K only, but not with soil Ex. K, CEC, Clay contents, OC and EC with the addition of 1µg mL^{-1} K, which account for 62% of K fixation rate variability. With the addition of 5µg mL^{-1} K, K fixation rate was correlated significantly with CEC which account for 72% of K fixation rate variability. The K fixation rate was correlated significantly with EC and Ex. K with the addition of 10µg mL^{-1} K, which account for 68% of K fixation rate variability. The K fixation rate was significantly correlated with Ex. K and OC with the addition of 20µg mL^{-1} K, which account for 67% of K fixation rate variability When the addition of K ranged from 60-200µg mL^{-1} K, the K fixation rate was correlated significantly with clay content and OC, which accounts for 59% to 66% of K fixation rate variability. In general, when the concentration of added K was lower (1-20µg mL^{-1} K), the CEC in the first component and Av. K in the second component were the main factors affecting the K

Table 3. Comparison of coefficients of determination (R^2) for the Freundlich, Langmuir and Temkin equations to the fixation data of the soils of District Ganderbal

Site	Equation		R^2	K fixation parameters of the Fruendlich equation	
				Fixation capacity 'a (g g^{-1})	Intensity of fixation 'b
S_1	Freundlich	Y= 0.665x + 0.374	0.993	2.35	1.50
	Langmuir	Y= 0.006x + 0.821	0.860		
	Temkin	Y= 34.98x 9.322	0.793		
S_2	Freundlich	Y= 0.532x + 0.335	0.926	2.16	1.88
	Langmuir	Y= 0.009x + 1.110	0.881		
	Temkin	Y= 24.26x 6.654	0.805		
S_3	Freundlich	Y= 0.674x + 0.374	0.978	2.36	1.48
	Langmuir	Y= 0.027x + 1.051	0.828		
	Temkin	Y= 12.77x 1.040	0.797		
S_4	Freundlich	Y= 0.514x + 0.317	0.925	2.07	1.94
	Langmuir	Y= 0.010x + 0.713	0.764		
	Temkin	Y= 26.70x 4.103	0.744		
S_5	Freundlich	Y= 0.694x + 0.225	0.978	1.67	1.44
	Langmuir	Y= 0.021x + 1.421	0.613		
	Temkin	Y= 12.47x 1.165	0.736		
S_6	Freundlich	Y= 0.694x + 0.127	0.965	1.33	1.44
	Langmuir	Y= 0.011x + 1.426	0.690		
	Temkin	Y= 19.93x 5.689	0.746		
S_7	Freundlich	Y= 0.583x + 0.530	0.966	3.38	1.71
	Langmuir	Y= 0.010x + 0.620	0.864		
	Temkin	Y= 24.31x + 0.210	0.753		
S_8	Freundlich	Y= 0.496x + 0.527	0.972	3.36	2.02
	Langmuir	Y= 0.011x + 0.711	0.924		
	Temkin	Y= 25.51x 3.955	0.804		
S_9	Freundlich	Y= 0.533x + 0.440	0.908	2.75	1.87
	Langmuir	Y= 0.012x + 0.786	0.636		
	Temkin	Y= 19.71x + 0.743	0.739		
S_{10}	Freundlich	Y= 0.685x + 0.344	0.970	2.21	1.45
	Langmuir	Y= 0.013x + 1.025	0.874		
	Temkin	Y= 16.51x + 0.446	0.812		

Table 4. Factor analysis for the effect of factors on the soil K fixation rate*

Effect factor	Component matrix		Rotated component	
	Component 1	Component 2	Component 1	Component 2
Av. K	0.995	0.102	0.922	0.388
Ex. K	0.997	0.080	0.912	0.409
CEC	0.543	-0.840	0.072	0.997
Clay	0.480	-0.144	0.352	0.757
OC	0.852	0.109	0.800	0.313
EC	0.541	0.474	0.702	-0.156

*Extraction method: Principal Component Analysis and Rotational method: Varimax with Kaiser Normalization

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Table 5. Regression equations and correlation coefficients of the linear relationship between K fixation rate and soil factors for the seven potassium additions

Added K concentration ($\mu g\ mL^{-1}$)	Linear regression equation*	R^2
1	KFR= 13.14 (t=8.41, p<0.001) + 5.63 (t=1.91, p<0.001) Av. K	0.624
5	KFR= 17.46 (t=6.52, p<0.002) + 9.94 (t=2.53, p<0.001) CEC	0.723
10	KFR= 22.88 (t=4.28, p<0.002) + 11.38 (t= 2.91, p<0.003) CEC + 1.56 (t=4.52, p<0.003) Ex.K	0.676
20	KFR=20.66 (t=2.31, p<0.004) + 0.958 (t=3.47, p<0.002) Ex. K + 0.852 (t=5.53, p<0.014) CEC	0.665
60	KFR=31.85 (t=5.37, p<0.001) + 26.41 (t=2.37, P<0.004) Clay + 1.42 (t=4.41, p<0.003) OC	0.661
100	KFR= 25.24 (t=4.06, p<0.001) + 28.94 (t=3.08, p<0.005) Clay + 2.53 (t=4.02, p<0.001) OC	0.644
200	KFR=12.87 (t=2.43, p<0.004) + 0.496 (t=3.041, p<0.003) Clay + 2.23 (t=3.67, p<0.001) OC	0.593

*The value in parentheses refer to the t value and p value of the significant level of the constant or the regression equation

fixation rate. When the concentration of added K was higher (60-200µg mL^{-1} K), the clay in the first component and OC in the second component were the main factors affecting the K fixation rate. Those results are consistent with the results of other studies (Huang and Jin 1996 and Pannu *et al*., 2003). Conti *et al* (2001) suggested that K fixation rate was correlated significantly (P<0.01) with the contents of soil organic carbon and exchangeable K. Shaimukhametov and Petrofanov (2008) reported that the loamy soil fixed more K than the sandy loamy soil irrespective of the rate of K fertilizer (0-2.5 cmol/kg).

The K-fixation was found maximum in Sumbal (S_7) soil having significant correlation clay content and CEC of the soil. Wangat (S_6) soil has the least fixation capacity which is likely due to its coarse texture and low CEC. For these results, it could be concluded that fixation of K was mainly governed by the clay content and CEC of the soil. HuiMin *et al.* (2009) and Zhang *et al*., (2009) also found the black soils (high clay content and CEC) fixed more K as compared to the red soils (low clay content and CEC).

There might be an interaction between or among those main factors that affect the K fixation. There were relationships among the four factors (i.e., Av. K, Ex. K, OC and EC) in the first component. Shaimukhametov and Petrofanov (2008) implied that the fixation of K in the unexchangeable form could be regarded as the buffering capacity of soil exchangeable K and that recently fixed K had higher availability for crops than K fixed earlier. Similarly, there were also relationships among the two factors (i.e., CEC and clay) in the second component. It was reported that soil CEC was correlated significantly with SOM and <0.002 mm clay contents (Gao and Chang 1996).

From evaluation and comparison of the Langmuir, Freundlich, and Temkin isotherm equations, it was concluded that the Freundlich isotherm equation explain the sorption phenomenon more accurately.

Our results also showed that the K fixation capacity was greater in the following sequence in the seven tested soils: Silty caly (S_7) > Silty clay loam (S_9) > Silty clay loam (S_8) > Silty clay loam (S_3) > Clay loam (S_1) > Sandy loam (S_{10}) > Silty loam (S_2) > Loam (S_4) > Clay loam (S_5) > Sandy loam (S_6) and was significantly correlated with CEC and clay content. Potassium fixation rate was mainly affected by CEC and Av.K with lower added K concentration and by clay and OC with higher added K concentration.

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Effect of Integrated Nutrient Management on Physico-Chemical Properties of Soil, Growth, Yield and Quality of Rice Under Irrigated Ecosystem of Uttar Pradesh

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Abstract: Higher organic carbon, electrical conductivity, bulk density and growth attributes *viz*. plant height, tiller and dry matter were recorded in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} and this treatment was significantly higher over all other treatments but which was at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} at all stages of crop. Higher pH was recorded at 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} and minimum pH was recorded at control treatment. Maximum grain and straw yield were recorded (4.6 and 6.4 t ha^{-1}) with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} and which was significantly superior to all others treatment. Nutrient uptake and nutrient available in soil were found in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} and this treatment was significantly to all others treatment but which was at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} at all stages of crop.

Key Words: INM, Organic Matter, Nutrient Uptake, Rice Yield, Soil Health

Rice is grown over on area of 148.36 million hectares with annual production of about 678 million tonnes. Rice contributes 43% of total grain production and 46% of the total cereal production of India (FAO, 2010). Among the rice growing countries India has largest area (44 million hectare) followed by China. Rice produced in India accounted for 21.60% of all world rice production (Ministry of Agriculture, 2010). The India's rice production reached to a record high of 104.32 million tonnes and productivity of rice 21.3 q/ha in 2011-2012. The average rice yield per hectare is highest in state of Punjab. To improve the production efficiency of rice, it is necessary to apply required dose of N, P, K and organic matter (Wani *et al*., 2012 and Upadhyay *et al*., 2011). Intensive cultivation and growing of exhaustive crops, accompanied by restricted use of organic manures and biofertilizers have made the soils not only deficient in the nutrients but also deteriorated the health resulting in decline in crop response to the recommended dose of N-fertilizer in the region. Non-Judicious enhancement of the N-fertilization further worsens the situation. Under such a situation, integrated plant nutrient system (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity. Use of chemical fertilizers in combination with the organic manures is essential to improve soil health (Bajpai *et al*., 2006). Continuous recycling of the green manures with organic amendments enhances the organic matter and also supplements the nutrient pool of the soil (Kumar *et al.,* 2008). Biofertilizers carried out in different part of country indicated the high production with maintaining the soil fertility. As compared to the chemical fertilizers, biofertilizers are cheaper, pollution free and renewable source of nutrient supply. Extensive use of chemical fertilizers caused environmental pollution and ecological damage and increased production cost (Mitsh and Day, 2006). Under these circumstances, integrated use of organic manures, inorganic fertilizers and biofertilizers has assumed great importance for sustainable production and maintaining soil health. The objective of this study was to find out the evaluation of integrated nutrient management practices under irrigated ecosystem of Uttar Pradesh.

MATERIAL AND METHODS

Crop Management and Experimental Design:

The field experiment was conducted during *Kharif* season of 2011-2012 on Research Farm of Department of Agricultural Chemistry and Soil Science, Udai Pratap Autonomous College, Varanasi (U.P.). The Research Farm is located at 25° 32' N latitude and 82° 97' E longitude with an elevation of 128.93 m above mean sea level. The soils of Varanasi formed on alluvial, deposited by river Ganga have predominance of illite, quartz, feldspars and illite minerals are partly inherited from micas which are predominant in the

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sand and silt fractions. There were six treatment combinations (Table 2) in randomized block design with 3 replications. Selection of 'Mansuri' rice varieties were sown on 15th July, 2011 and harvesting was done on 26th November, 2011, respectively. Rice crop was fertilized as per treatments.

Soil and Plant Sampling: The soil samples were taken each treatment and air dried, crusted with wooden roller and removed by passing through 2 mm round hole sieve. Soil samples collected were analyzed for various chemical properties such as organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), 0.5 M $NaHCO_3$ (pH 8.5) extractable phosphorus (Olsen *et al.*, 1954), 1 N NH_4 OAC extractable potassium and available sulphur (Chesnin and Yien, 1951).

Growth attributes *viz.* plant height (cm), number of tillers (per meter row length) and dry matter (g) was determining on five tagged plants and averaging them. The grain yield of net plot after cleaning and proper drying was recorded in gram and converted to t ha^{-1} by multiplying with appropriate conversion factor. After threshing stem and chaff weight per plot were recorded and added treatment wise. Then, these were converted to t ha^{-1} by multiplying with appropriate conversion factor. Harvest index was calculated by dividing economic yield, *i.e.*, grain yield with biological yield (grain and straw) and expressed as percentage.

$$\text{Harvest index (\%)} \quad \frac{\text{Economic yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}}$$

Effect on Physico-Chemical Properties of Soil: Data of the soil pH slightly increased from transplanting of the seedling to the harvest of the crop. Significant effect of integrated use of inorganic fertilizers, organic manures and biofertilizer was recorded at all growth stages . Highest pH was recorded with addition of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1}. In respect of soil pH, various treatments could be arranged in the order $T_1>T_3>T_4>T_6>T_2>T_5$ with soil pH varied from 7.70 to 7.74, 7.71 to 7.76, 7.73 to 7.78, 7.74 to 7.79, 7.77 to 7.81 and 7.80 to 7.89 at 30 60 DAT and at harvest, respectively (Table 2). The release of organic acid during decomposition of organic manures might have resulted in decline in soil pH. Significantly higher organic carbon content was recorded in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (T_5) as compared to other treatments. The organic carbon content of soil under different treatments was found in the order $T_5>T_3>T_6>T_4>T_2>T_1$ with values were 0.60, 0.58, 0.55, 0.53, 0.50 and 0.44 at 30 DAT 0.57, 0.55, 0.53, 0.50, 0.44 and 0.42 at 60 DAT and 0.52, 0.51, 0.49, 0.47, 0.42 and 0.38% at harvesting under respective treatments (Table 2). Higher organic carbon content in plots received higher amount of FYM and carpet waste may be attributed to higher amount of organic carbon content in the FYM and carpet waste. The increase in organic carbon content in the manurial treatment combination is attributed to the direct incorporation of organic matter in the soil on the subsequent decomposition of these materials might have resulted in the

Table 1. Nutrient contents of Farm yard manure (FYM), Carpet waste and Phosphate solublizing bacteria

Parameters	Organic sources		
	Farm yard manure (FYM)	Carpet waste	Phosphate solublizing bacteria (100 g)
Nitrogen (%)	0.5	12.0	0.5
Phosphorus (%)	0.4	0.05	3.2
Potassium (%)	0.9	0.05	0.2

Table 2. Effect of integrated nutrient management on physio-chemical properties of soil

Treatment	pH	OC (%)	EC	Bulk density	pH	OC (%)	EC	Bulk density	pH	OC (%)	EC	Bulk density
	30 DAT (Days after transplanting)				60 DAT (Days after transplanting)				At harvest			
T_1	7.70	0.44	0.30	1.22	7.72	0.42	0.28	1.24	7.74	0.38	0.28	1.27
T_2	7.77	0.50	0.33	1.28	7.79	0.44	0.34	1.30	7.81	0.42	0.36	1.33
T_3	7.71	0.58	0.28	1.24	7.74	0.55	0.29	1.25	7.76	0.51	0.30	1.28
T_4	7.73	0.53	0.27	1.27	7.76	0.50	0.31	1.29	7.78	0.47	0.32	1.30
T_5	7.80	0.60	0.35	1.30	7.81	0.57	0.37	1.32	7.89	0.52	0.38	1.35
T_6	7.74	0.55	0.31	1.27	7.77	0.53	0.32	1.28	7.79	0.49	0.33	1.29
LSD (P 0.05)	NS	0.03	0.02	0.03	NS	0.03	0.02	0.03	NS	0.03	0.02	0.03

T_1- Control, T_2- 100 % N through urea + PSB + 20 kg S ha^{-1}, T_3 - 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1}, T_4 - 25 % N through FYM + 75% N through urea + PSB + 20 kg S ha^{-1}, T_5 - 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1}, T_6 - 25 % N through carpet waste +75% N through urea + PSB + 20 kg S ha^{-1}

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enhanced organic carbon content of soil (Basker, 2003 and Tolanur and Badanur, 2003).

Maximum EC was recorded in (T_5) 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} followed by T_2, T_6, T_1, T_3 and T_4 at all stages of crop growth and difference in values of EC among various treatments was found to be statistically significant (Table 2). The bulk density of soil increased with advancement in growth stages and maximum bulk density was recorded at harvesting of crop under all treatments. Significantly higher bulk density was recorded in 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1}. The effect of various treatment of bulk density of soil was found in order $T_5>T_2>T_4>T_6>T_3>T_1$ with varied from 1.35 to 1.30, 1.33 to 1.28, 1.30 to 1.27, 1.29 to 1.27, 128 to 1.24 and 1.27 to 1.22 g m^{-1} at 30, 60 DAT and at harvest, respectively (Table 2). Addition of organic manures decreased the bulk density of soil might be due to the fact that better aggregation, high porosity and low bulk density of organic matter. It was also observed that the bulk density of rice plot increased with time might be due to natural compaction and consolidation (Roy *et al.*, 2013).

Effect on Growth Attributes: The effect of different treatments of organic manures, bio-fertilizer and inorganic fertilizers on plant height, tiller per meter row length and plant dry matter was found significantly under respective treatments. Highest plant height, tiller per meter row length and plant dry matter was recorded with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} and this treatment was significantly increased the plant height, tiller per meter row length and plant dry matter over other treatments at different growth stages, respectively (Table 3). This could be attributed to higher and continuous supply of nutrients in organic manures treated plots which was significantly increased the growth characteristics of rice (Hasanuzzaman *et al.*, 2010).

Effect on Yield: Significantly higher grain yield was obtained with the application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (4.6 t ha^{-1}) over T_6, T_4, T_2 and T_1 (3.1 t ha^{-1}) but which was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3). Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} was 6.9, 17.9, 24.3, 31.4 and 48.4 % grain yield increased over T_3, T_6, T_4, T_2 and T_1, respectively (Table 4). In case of straw yield was obtained with the application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (6.4 t ha^{-1}) and this treatment was significantly higher straw yield over T_6, T_4, T_2 and T_1 (4.2 t ha^{-1}) but which was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3). Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} was 6.7, 18.5, 23.1, 36.2 and 52.3 % straw yield increased over T_3, T_6, T_4, T_2 and T_1, respectively (Table 4). The combined application of inorganic and organic sources produced higher grain and straw yield than inorganic alone might be attributed to higher and continuous supply of nutrient and improvement in physical environment of soil which increased significantly the yield characteristics of the rice. This is in agreement with findings of Selvakumari *et al.* (2000), Kumar *et al.*, (2013) and Roy *et al.* (2013) also obtained significantly higher grain and straw yield of rice crop by integrated of organic and inorganic sources of nitrogen.

Effect on Nutrients Uptake: Data revealed that the significant effect of integrated use of inorganic fertilizers, organic manures and biofertilizer on nitrogen uptake. Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} was recorded maximum NPK uptake of rice and this treatment was significantly higher NPK uptake than other treatment combinations. The minimum NPK uptake of rice was observed in control (Table 4). Application of N through organic sources may be ascribed to the release of K from the K-bearing minerals by complexing ascent or organic acids produced during decomposition of organic manure (Kumari *et al.*, 2010, Nath *et al.*, 2010 and Roy *et al.*, 2013). This might be due to the improved physical properties of soil with better N availability to the crop. Sulphur uptake was maximum with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} due to chelating action of organic compounds which prevents these cations from fixation, precipitation, oxidation and leaching (Gogoi *et al.*, 2010, Kumar *et al.*, 2013 and Roy *et al.*, 2013).

Effect on Available Nitrogen: The available nitrogen status of soil decreased continuous with advancement in growth stage (Table 4). Various treatments of inorganic fertilizers, organic manures and biofertilizer in respect of available nitrogen content could be arranged in order $T_5>T_3>T_6>T_4>T_2>T_1$. Available nitrogen content of surface soil increased appreciably with the application of manures along with fertilizers as compared to sole application of NPK fertilizers. Application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} significantly increased available N content over different treatments, but which was at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} treatment at all growth stages. Increase in available N might be due to the direct addition of N through FYM and improved microbial activities, which might have converted organically bound N to inorganic forms (Singh and Dhar, 2011, Kumar *et al.*, 2013 and Roy *et al.*, 2013).

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Table 3. Effect of integrated nutrient management on growth attributes of rice

Treatment	Plant height (cm)	Tillers (m^{-1} row length)	Dry matter (g)	Plant height (cm)	Tillers (m^{-1} row length)	Dry matter (g)	Plant height (cm)	Tillers (m^{-1} row length)	Dry matter (g)
	30 DAT (Days after transplanting)			60 DAT (Days after transplanting)			at harvest		
T_1	55.0	25	17.0	64.3	48	39.0	70.7	44	47.2
T_2	56.6	29	24.0	67.3	50	43.3	71.9	47	52.4
T_3	65.7	35	44.0	80.4	62	65.0	86.4	55	78.6
T_4	59.6	30	32.0	68.0	53	45.6	75.3	49	55.2
T_5	67.5	38	58.0	83.5	68	81.3	90.1	60	98.4
T_6	61.4	31	39.0	78.2	56	61.6	80.2	50	74.5
LSD (P 0.05)	1.8	0.9	2.7	2.2	1.5	3.8	2.3	1.5	4.6

Table 4. Effect of integrated nutrient management on grain yield, straw yield and nutrient uptake of rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Nutrient uptake (kg ha^{-1})			
				N	P	K	S
T_1	3.1	4.2	42.5	12.6	7.4	60.6	4.5
T_2	3.5	4.7	42.7	16.4	9.4	71.4	7.7
T_3	4.3	6.0	41.7	21.0	13.6	114.0	10.2
T_4	3.7	5.2	41.6	18.3	10.4	81.0	8.1
T_5	4.6	6.4	41.8	22.7	14.2	132.0	12.2
T_6	3.9	5.4	41.9	19.6	12.7	102.5	9.8
LSD (P 0.05)	0.3	0.4	NS	0.6	0.4	3.0	0.3

Table 5. Effect of integrated nutrient management on available soil nutrient content of rice

Treatment	Available nutrient content (kg ha^{-1})											
	N	P	K	S	N	P	K	S	N	P	K	S
	30 days after transplanting				60 days after transplanting				At harvest			
T_1	235.5	16.2	218.2	10.0	225.1	13.5	211.3	8.6	216.6	10.0	197.3	6.8
T_2	251.6	16.8	225.6	10.6	246.0	14.7	222.0	9.2	230.6	10.6	203.2	8.0
T_3	270.2	21.8	246.4	15.7	259.5	18.9	237.0	12.8	246.3	14.7	224.1	11.6
T_4	257.4	17.6	231.1	12.0	254.1	15.2	226.0	10.3	238.2	11.5	212.5	8.9
T_5	276.3	22.4	253.1	16.0	263.2	19.3	243.0	13.1	250.1	15.0	229.6	11.7
T_6	261.1	19.0	236.7	13.0	255.7	16.0	230.0	11.2	241.3	12.1	216.0	10.0
LSD (P 0.05)	7.3	0.6	6.7	0.4	7.1	0.5	6.4	0.3	4.7	0.4	6.1	0.3

Effect on Available Phosphorus: In general, available phosphorus content of soil gradually decreased with age of crop. Significant effect of integrated use of mineral fertilizer with organic manures was recorded. The effect of addition of organic of soil was found in the order $T_5>T_3>T_6>T_4>T_2>T_1$. Maximum available phosphorus was recorded with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} application and this treatment was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} and which was significantly superior over all other treatments at 30, 60 DAT and at harvest. Increase in P availability might be due to the fact that organic materials form a cover on sesquioxides and thus reduce the phosphate fixing capacity of the soil and increased phosphorus solubilization for the native soil pool. The benefit of using organic manure like FYM was due to release of aliphatic and aromatic hydroxy acids and humates that leads to higher availability of nutrients (Kumar *et al.*, 2013). Available P enhanced due to CO_2 released and organic acid produced during decomposition, which helps in solubilizing native P. The organic matter (humus) may also reduce the fixation of phosphate by providing protective cover on sesqueoxides and chelating cations, which in turn enhanced the availability of P (Singh *et al.*, 2008 and Roy *et al.*, 2013).

Effect on Available Potassium: The result showed that the available potassium status of soil decreased with days after transplanting and effect of various treatment of organic manures, biofertilizer and inorganic fertilizers on available potassium were found in the order $T_5>T_3>T_6>T_4>T_2>T_1$. The available K content of the recording data was significantly higher in application of 50 % N through

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carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (T_5) as compared to rest of treatments at 30, 60 DAT and at harvest stage except, application of 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3). Increase in available K due to organic manures application may be attributed to direct addition of potassium to the available pool of the soil. Beneficial effect of organic manures and biofertilizer on available K due to reduction of K-fixation, solubilization and release of K due to the interaction of organic matter with clay, besides the direct potassium addition to the potassium pool of the soil (Singh *et al,* 2008, Roy *et al.,* 2013 and Kumar *et al.*, 2013).

Effect on Available Sulphur: The result indicated that the available sulphur status of soil decreased with days after transplanting whereas the effect of various treatments of organic manures, biofertilizer and inorganic fertilizers on available sulphur was found in the order $T_5>T_3>T_6>T_4>T_2>T_1$. Maximum available phosphorus was recorded with 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} (T_5) application and this treatment was statistically at par with 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} (T_3) and which was significantly superior over all other treatments at 30, 60 DAT and at harvest. Increase in available sulphur due to organic manures and biofertilizer application may be attributed to direct addition of sulphur to the available pool of the soil and reduction in losses and fixation of S through various mechanisms. Similar results were also report by Tiwari *et al.* (2002), Yadav and Kumar (2009) and Roy *et al.* (2013).

In conclusions, it could be recommended that application of 50 % N through carpet waste + 50% N through urea + PSB + 20 kg S ha^{-1} treatment showed the highest growth attributes, yield, nutrient uptake and available nutrients among all other treatments. However, 50 % N through FYM + 50% N through urea + PSB + 20 kg S ha^{-1} was applied the next best treatment in these respects under irrigated ecosystem of Eastern Uttar Pradesh.

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Fertilizer Prescription for Targeted Yield of Rice (*Oryaza sativa* L var. Saryu-52) in an Inceptisol of Varanasi

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Abstract: The development of prescription based fertilization recommendations for a given soil crop fertilizer situation takes into account the soil fertility status as well as crop needs and is thus based on balanced nutrition of crops. So, the target yield concept involves fertilizer recommendation based on yield targets to be achieved taking into consideration the contribution of soil available nutrients and fertilizer nutrients for total uptake. Three field experiments were conducted at farmers fields to check the validity of the fertilizer adjustment equation for rice crop (cv. Saryu-52) by comparing control, farmers practice, general recommended doses of fertilizers and fertilizer doses based on soil test crop response (STCR) for 45 q ha^{-1} for ascertaining the economics of each practice. Results of the study showed the superiority of the target yield concept over the other practices as it gave higher yield and optimal economics returns. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in rice thus establishing the utility of the adjustment equations for recommending soil test based fertilizer application to the farmers.

Key Words: Benefit Cost Ratio, Target Yield, Fertilizer, Farmer Practice, Soil Test.

Rice (*Oryza sativa L.*) is the major crop in Uttar Pradesh and occupies 5.86 mha of land, which comprises of 13.82% of total area under rice in India. Uttar Pradesh is the leading producer (14.41 Mt) of rice and rank 2nd in the country (Anonymous, 2013). Fertilizer is a costly input and, therefore, its economics before use should be evaluated from the yield production per unit of nutrient applied. The efficiency of added fertilizer depends upon many factors like nature of the soil, availability of the nutrient status of the soil, the climate, crop and its variety, management practices, etc. Soil testing enables to evaluate the nutrient supplying capacity of the soil and being widely used to work out nutrient requirement of the crops. Fertilizer requirements of different crops vary due to their differential production potential and ability to mine nutrients from native and fertilizer sources. Therefore, the quantity of fertilizers to be applied to crops depends upon the initial nutrient status of the soil and thereby, soil test value need considerable attention. The fertilizer requirements of crops also depend upon yield targets to be achieved. For achieving a definite target yield of a crop, a definite quantity of nutrients must be applied to the crop and this requirement of nutrients can be calculated by taking in to consideration the contribution of soil available nutrients and fertilizer nutrients for total uptake. This forms the basis for fertilizer recommendations for targeted yield of crops. Farmers are using excess chemical fertilizers to achieve higher yield but the decision on fertilizer use requires knowledge of the expected crop yield and response to nutrient application (1.214, 0.418 and 0.074 Mt per ha fertilizer consumption in the district in terms of NPK). Field-specific balanced amounts of primary nutrients (N, P and K) were prescribed based on crop based estimates of the supply of N,P and K and by modelling the expected yield response as a function of nutrient interaction (Ramamurthy *et al.*, 2009). These equations were developed after establishing significant relationship between soil test values and the added fertilizer. This study was conducted keeping the above facts in view and non-availability of STCR data for rice in eastern Uttar Pradesh.

The objective of this study was to evolve a sound basis of fertilizer prescriptions for rice crop in alluvial soil (Inceptions) at different soil fertility levels under the conditions of fertilizer scarcity and to ensure maximum fertilizer use efficiency. The present study was, therefore, conducted at farmer's fields on rice crop for comparing control, farmers practice, soil test based general recommendation dose of fertilizer and yield target concept for ascertaining the economics of fertilizer application of each practice.

MATERIAL AND METHODS

Field experiments were conducted at farmer's fields in three villages viz., Khewashipur (location I), Bhatshar (location II) and Loharpur (location III) of Varanasi district,

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Uttar Pradesh, India during year *kharif* 2013 (15.06.2013 to 10.10.2013) on alluvial soil (Inceptions). Before sowing of crop, surface soil samples (0-15 cm) were collected from the experimental fields, processed for analysis and analyzed for various physico-chemical properties. Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen method (Olsen *et al.*, 1954) and available potassium by the ammonium acetate method (Hanway and Heidal, 1952) as described by Jackson (1973). Four treatments viz., control, farmers practice, general recommended dose of fertilizer and fertilizer doses based on soil test crop response (STCR) for target yield 45 q ha^{-1} of rice (cv. Saryu-52) were evaluated. The targeted yield of crop was decided as per yield potential of varieties. Soil resource inventory of the study area in given in the Table 1. The fertilizer adjustment equations are derived by the All India Coordinated Research Project, Institute of Agricultural Science, B.H.U., Varanasi centre. Doses of nitrogen, phosphorus and potassium were calculated with the help of fertilizer adjustment equations as follow:

With FYM:

$$FN = 4.74\,T - 0.49\,SN - 0.34ON$$

$$FP_2O_5 = 1.53\,T - 1.41\,SP - 0.09OP$$

$$FK_2O = 2.92\,T - 0.35\,SK - 0.11OK$$

Where - T = Yield target (t ha^{-1})

FN = Fertilizer N (kg ha^{-1})

FP_2O_5 = Fertilizer P (kg ha^{-1})

FK_2O = Fertilizer K (kg ha^{-1})

SN = Soil available nitrogen (kg ha^{-1})

SP = Soil available phosphorus (kg ha^{-1})

SK = Soil available potassium (kg ha^{-1})

ON = Amount of N applied through FYM (kg ha^{-1})

OP = Amount of P applied through FYM (kg ha^{-1})

OK = Amount of K applied through FYM (kg ha^{-1})

One third dose of N and full dose of P_2O_5 and K_2O were applied as basal application at transplanting time and rest amount of N was applied in two equal splits at 25 and 50 days after transplanting of the crop. Nitrogen, phosphorus and potassium were supplied through urea, single super phosphate and muriate of potash, respectively.

The pH varied from 7.2 - 8.4, organic carbon 0.28 - 0.56 % (Table 1). The soils were low in available nitrogen (160-180 kg ha^{-1}), low in available phosphorus (10-15 kg ha^{-1}) and medium in available potassium (160-180 kg ha^{-1}).

RESULTS AND DISCUSSION

From the field experiment, the basic data on nutrient requirement (NR) for producing one quintal grain yield of rice, per cent contribution of nutrients from soil (%CS), fertilizer (%CF) and farm yard manure (%CFYM) were evaluated. These basic parameters were used for developing the fertilizer prescription equations under NPK with farm yard manure. The nutrient requirement of N, P_2O_5 and K_2O were 2.56, 0.56 and 2.21 kg q^{-1} of grain yield, respectively. The per cent contribution of nutrients from soil, fertilizers and farm yard manure were found to be 26.35, 54.03 and 18.59 for N, 51.17, 36.35 and 3.10 for P_2O_5 and 26.14, 75.68 and 8.56 for K_2O, respectively. It was noted that contribution of potassium from fertilizer for rice was higher in comparison to soil. This high value of potassium could be due to the interaction effect of higher doses of N, P coupled with priming effect of starter K doses in the treated plots, which might have caused the release of soil potassium form, resulting in the higher uptake from the native soil sources by the crop (Basavaraja *et al.*, 2011). Similar type of higher efficiency of potassic fertilizer was also reported for rice by Ahmed *et al.* (2002) in alluvial soils and for finger millet by Kadu and Bulbule (2007). Contribution of available nutrient from FYM is low, which might be due to lower mineralization rate of FYM (Sachan *et al.*, 1981). However, in the case of P_2O_5, the contribution was more from soil than fertilizer.

In all the cases, yield of 45 q ha^{-1} for rice (variety–Saryu-52) was achieved with in ± 10 per cent of the target yield (Table 2). At third location, the benefit cost ratio 2.03 was higher comparison to first and second locations. Generally, the rice yield was higher when fertilizer was applied on target basis as compared to that obtained through the farmers practice and general recommended dose of fertilizers. At all sites, grain yields of rice through general recommendation (GRD) of fertilizers lagged behind the yield obtained at 45 q ha^{-1} fixed target. These results find the support of Basavaraja *et al.* (2011), Deshmukh *et al.* (2012) and Avtari *et al.* (2010).

Target yield of 45 q ha^{-1} has been achieved with comparatively lower application of N and P_2O_5 fertilizers but higher application of K_2O, in comparison to doses applied in farmer's practice and soil based recommendations. Although, the fertilizer application based on this concept is more balanced, profitable and helps in long term maintenance of soil fertility, but due to inadequacies in managerial skills and aberrant weather conditions, actual yield obtained deviates from the target fixed in some of the cases. By taking into consideration the cost of fertilizer applied to the crops and value of additional produce over farmer's, the benefit of other approaches of fertilizer application over farmer's practice was calculated (Table 2). Several studies carried out at experimental farms and under

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Table 1. Physico-chemical properties of the experimental fields

Locations	Physico-chemical properties			Available nutrients (kg ha^{-1})		
	pH	EC (dSm^{-1})	OC (%)	N	P	K
Location-I	7.2-8.2	0.30-0.42	0.28-0.36	160.0	10.0	180.0
Location-II	7.3-8.4	0.40-0.58	0.38-0.56	180.0	10.0	160.0
Location-III	7.5-8.4	0.58-0.70	0.40-0.55	160.0	15.0	180.0

Table 2. Economics of verification trails for rice crop

Treatments	Doses NPK (kg/ha) and FYM (t/ha)	Mean yield (kg/ha)	Additional yield over control (kg/ha)	Value of additional yield (Rs/ha)	Cost of fertilizer and FYM (Rs/ha)	Net benefit (Rs/ha)	B/C ratio
Location - I : Village-Khewashipur							
Control	0-0-0-0	2166	-	-	-	-	-
FP	110-35-35-0	2966	800	8800	4800.75	3999.25	0.83
GRD	120-60-60-0	3780	1614	17754	7037.40	10716.60	1.52
TY 45 q ha^{-1}	119-52-64-5	4560	2394	26334	9675.05	16658.95	1.72
Location - II : Village- Bhatshar							
Control	0-0-0-0	2000	-	-	-	-	-
FP	110-35-35-0	3000	1000	11000	4800.75	6199.25	1.29
GRD	120-60-60-0	3800	1800	19800	7037.40	12762.60	1.81
TY 45 q ha^{-1}	119-52-64-5	4550	2550	28050	9675.05	18374.95	1.90
Location - III: Village-Loharapur							
Control	0-0-0-0	2000	-	-	-	-	-
FP	110-35-35-0	2866	866	9526	4800.75	4725.25	0.98
GRD	120-60-60-0	3833	1833	20163	7037.40	13125.60	1.87
TY 45 q ha^{-1}	119-52-64-5	4666	2666	29326	9675.05	19650.95	2.03

Note: Paddy @ Rs.11.00/kg, N @ Rs.17.39/kg, P_2O_5 @ Rs.56.25/kg, K_2O @ Rs.26.66/kg, FYM @ Rs. 0.60/kg. FP: Farmers practice, GRD: General recommendation dose, TY: Target yield, B C ratio: Benefit cost ratios.

farmer's field conditions have established the validity of target yield concept for different crops under variable soil type and agro climate conditions (Dhillon *et al*., 2006). The benefit cost ratio of rice crop at all locations (Table 2) suggests that target yield concept gives higher yields and hence better economic returns than farmer practice and general recommendation. Also, the target yield treatment recorded higher percentage of target and BC over other treatments. The favourable complementary influence of organic and inorganic on chemical, physical and biological properties of soil under target yield treatment would have resulted in higher yields of rice crop.

The results of the study have clearly brought out the superiority of fertilization based on target yield concept over traditional approaches as reflected through higher yields and optimal economic returns. The farmers practice was poor yielder in all the locations. The results showed a very close correspondence between targeted yields and the yield obtained and are an evidence of the usefulness of soil testing within limits of variation under field conditions. The equation generated can be used for making fertilizer recommendations for targeted yields of rice in Inceptisol of eastern Uttar Pradesh.

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Performance of Fodder Maize Under Zero Tillage, Bed Planting and Nitrogen in Comparison to Conventional Tillage for Seed Production

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Abstract: The experiment was conducted to find out the planting method and nitrogen level for enhancing the seed yield of fodder maize (*Zea mays* L.). The treatment comprised of three planting methods as zero tillage (ZT), conventional tillage (CT) and bed planting (BP) and four nitrogen levels (0, 100, 125 and 150 kg N/ha). Results revealed that maize fodder (variety J 1006) seed yield did not vary with ZT, CT and BP because biometrical parameters like plant height, leaf area, dry matter accumulation, stover yield, shelling percentage, 1000 grain-weight were also not varied with methods of planting. Nitrogen application of 150 kg N/ha produced the significantly higher seed yield than 0, 100 and 125 kg N/ha.

Key Words: Bed planting, Conventional Tillage, Fodder Maize, Nitrogen, Seed Production, Zero Tillage.

Maize (*Zea mays* L.) is the third most important cereal crop next to rice and wheat and has the highest production potential among the cereals. In Punjab, maize was grown on 133 thousand hectares with total production of 491 thousand tonnes during 2011-12 (Anonymous, 2012). However, the average yield of maize is 27.3 q/ha which is rather low as compared to yield of developed countries. So, there is scope to increase its productivity through agronomic interventions and it can also be an attractive alternative to rice for diversification by the farmers of the state. Maize production can be enhanced by adoption of proper planting method and use of essential nutrients. For raising the crop yield fertilizer impact is one of the major factors and it contributes about 50% to yield performance. The planting of maize in *kharif* also experiences high rainfall during monsoon season which often results in temporary flooding on flat planted crop. Thus there is a need to try various planting methods in order to reduce its water requirement when sown during end of May and also to save it from temporary flooding damage caused due to monsoon rains. Zero tillage, ridge or bed sowing also gave higher yield than the flat sowing method. Freeman *et al.* (2007) reported that planting of maize on bed provides a good option for managing water, nutrients and weeds. The bed planting system have number of advantages like better irrigation management, increased availability of nutrients to crop roots, better crop establishment, better weed management through inter bed cultivation and less soil compaction and also helps to increase aeration in root zone and ensure good plant stand by increasing emergence particularly in crusting type soil. Singh and Singh (2012) observed ridge method to be better than flat and raised used planting in winter maize. The main objective of the study is to find out the suitable planting method and nitrogen requirement for enhancing the seed yield of fodder maize.

MATERIAL AND METHODS

Field experiment was carried out at the students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana (36° 54' North latitude and 75° 48' East longitudes; 247 meters above mean sea level). The treatment consisted of three planting methods zero tillage (ZT), conventional tillage (CT) and bed planting (BP) and four nitrogen (N) levels (0,100,125 and 150 kg N/ha) with planting methods in vertical strip and nitrogen levels in horizontal strip. The treatment was replicated three times in strip plot design. The soil of experimental field was sandy loam in texture and normal in pH, EC and organic carbon, medium in available N (125 kg N/ha), P (12.3 kg P_2O_5/ha) and K (115.0 kg K_2°/ha). Nitrogen was applied in the form of urea in three splits as per treatment. One third at sowing and other one third at knee high stage near the plant base and remaining one third at pre tasseling stage. The row-to-row spacing was 50 cm and plant-to-plant spacing was 20 cm. The crop husbandry was as per recommended package of practices. Five plants were randomly selected from the each plot and tagged. The plant height from the base of the stem to the base of the topmost unfolded leaf was recorded periodically at 10 days interval starting from the day of sowing. The mean plant height of five tagged plants was

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computed. The periodic dry matter accumulation and leaf area index was determined by randomly selecting three plants per plot. Five cobs were selected at random from each plot for measuring cob length, 1000- grain weight; stover yield and shelling percentage were determined by randomly selecting a sample from the pool of harvested seeds from each plot. Grain yield (q/ha) was determined by recording the seed yield after shelling. The shelling percentage (SP) was calculated by dividing the grain weight of five cobs by the total weight of five cobs and multiplying it by 100.

RESULTS AND DISCUSSION

Growth Parameters: The plant height increased slowly between 20 and 40 DAS, increase more pronounced between 40 to 60 DAS and increase was very slow between 80 DAS and at harvest under different planting methods and N levels (Table 1). It shows that increase in plant height from 40 to 60 DAS is the grand growth period of the maize crop. Plant height increased with increase in N from 0 to 150 kg/ ha at all the stages of the crop growth. At 60 DAS and at harvest, application of 150 kg N/ha produced significantly taller plant over the control and 100 kg N/ha, but at par with 125 kg N/ ha. Whereas, at 80 DAS, 150 kg N/ha was at par with 125 and 100 kg N/ha, but significantly higher than control (147.9 cm). The improvement in plant height with each successive increment of nitrogen might be attributed to the fact that nitrogen is an integral part of protein, the building blocks of plant and it also helps in maintaining higher auxin level, which might have resulted in better plant height (Kumar, 2009). These results are in close association with Rizwan *et al.* (2003) and Harikrishna *et al.* (2005) who reported a non-significant effect of nitrogen application on maize plant height. Increasing nitrogen level from 120 kg /ha to 200 kg /ha also increased the plant height of hybrid maize varieties. Higher N applications increase the cell division, cell elongation, nucleus formation as well as green foliage. It also encourages the shoot growth. Higher doses of nitrogen increased the chlorophyll content, which increased the rate of photosynthesis and extension of stem resulting increased plant height (Thakur *et al.*, 1997).

Leaf area varied significantly at 20, 40 and 80 DAS due to different planting methods. It was increased progressively up to 80 DAS and at harvest decreased substantially as compared to 80 DAS under different planting methods and N levels (Table 1). The bed planted method recorded significantly better leaf area than other two methods at 20, 40 and 80 DAS. It could be due to better water and nutrient absorption by the crop resulted in better leaf growth. However, at 60 DAS and at harvest, leaf area was higher under bed planting method but the differences were non-significant among the different planting methods. Leaf area with 150 kg N/ha was significantly at par with 125 kg N/ha and both these levels were significantly better than 100 and 0 kg N/ha at 20, 40 and 60 DAS. However, application of 150 kg N/ha gave significantly better leaf area over the rest of the N levels at 80 DAS and harvest. The increase in leaf area with increasing nitrogen levels might be due to better crop growth with higher N availability (Vedivel *et al.*, 2001).

The dry matter accumulation (DMA) increased progressively with advancement of age and the maximum values were recorded at harvest. Among the planting methods, BP showed significantly more DMA as compared to CT and ZT at 30 DAS (Table 2). At other growth stages, BP recorded comparatively more DMA as compared to other planting methods. High DMA in bed planted crop was due to better growth owing to better water and nutrient utilization.

DMA increased with the increment of N levels up to the highest level tried at all the growth stages. However, 150

Table 1. Effect of planting methods and nitrogen levels on plant height and leaf area at different stages of Fodder maize

Treatment	Plant height (cm)					Leaf area (cm^2)				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Planting method										
ZT	22.1	75.5	158.6	176.7	194.4	77.8	107.3	212.6	247.8	223.2
CT	23.0	83.7	160.1	185.9	201.4	86.1	121.2	218.8	258.3	227.3
BP	23.1	89.6	160.8	187.4	207.9	90.1	124.5	241.4	275.8	227.8
CD(p=0.05)	NS	4.2	NS	NS	NS	2.2	2.3	NS	16.5	NS
Nitrogen level (kg/ha)										
0	21.5	79.1	140.0	147.9	169.6	59.0	75.3	151.5	180.8	148.6
100	22.7	80.5	159.3	192.2	208.3	90.2	117.3	225.5	276.2	243.2
125	23.2	81.9	165.8	199.4	210.5	94.2	139.0	254.2	277.8	250.1
150	23.3	90.2	168.8	201.4	216.5	95.3	140.9	266.2	307.7	262.4
CD(p=0.05)	NS	NS	5.3	16.3	7.0	2.7	2.1	14.7	24.6	9.5

DAS –Days after Sowing

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Table 2. Effect of planting methods and nitrogen levels on dry matter accumulation, yield and yield attributes

Treatment	Dry matter accumulation per plant (g)				Cob length (cm)	Grain yield (q/ha)	Stover yield (q/ha)	Shelling (%)	1000-grain weight (g)
	30 DAS	50 DAS	70 DAS	80 DAS					
Planting method									
ZT	37.4	62.5	144.0	157.6	8.7	44.4	177.1	50.1	168.1
CT	39.9	62.5	144.9	158.5	11.1	44.6	178.7	50.4	178.9
BP	45.8	63.0	147.2	159.9	12.7	48.0	197.6	50.8	182.5
CD (p=0.05)	0.6	NS	NS	NS	0.7	NS	NS	NS	NS
Nitrogen level (kg/ha)									
0	34.5	48.2	124.6	140.8	6.0	21.0	144.9	36.8	132.5
100	36.5	59.1	135.8	147.7	9.8	45.3	171.8	46.7	183.9
125	42.4	65.7	153.6	166.2	13.5	53.0	207.4	57.2	193.0
150	50.8	77.0	167.4	180.0	14.0	63.3	213.7	61.0	196.7
CD (p=0.05)	1.2	2.5	4.2	4.9	1.2	3.0	20.0	3.4	21.7

DAS –Days after Sowing

kg N/ha showed significantly better DMA than other N levels at all stages of growth. Significant increase in DMA at each increment of N level has also been reported by Singh *et al.* (2003).

Yield and Yield attributes: BP showed significant more cob length than CT and ZT. Among all the methods of planting, zero tillage showed the minimum cob length. The cob length was statistically comparable under 125 kg N/ha and 150 kg N/ha, but differed significantly under control and 100 kg N /ha. Paradkar and Sharma (1993) reported a positive effect of N application on cob length of maize. Costa *et al.* (2002) reported that cob length increased when N level was increased from 0 to 85 kg /ha. Bakht *et al.* (2007) reported that maximum cob length (15.67cm) was produced in plots receiving 200 Kg N/ha followed by plots treated with 160 and 120 Kg N/ha.

The data presented in Table 2 showed that method of planting had no significant effect on the 1000-grain weight. Bed planted crop recorded the maximum 1000-grain weight followed by CT and ZT. Maximum 1000-grain weight was recorded at 150 kg N/ha (196.7 g), which was at par with 100 kg N/ha and 125 kg N/ha but significantly differed with control level of nitrogen. Maqsood *et al* (2001) reported that high levels of N markedly increased 1000-grain weight. The maximum SP was recorded from the BP plots (50.8 %), which was comparatively high as compared to CT and least in ZT. Higher value of SP was showed by 150 kg N/ha, which was significantly high as compared to 125, 100 kg N/ha and control, which was 3.8, 14.3 and 24.2 % more shelling as compared to other N levels. The results are in close agreement with the findings of Hussaini *et al.* (2001).

Grain and Stover yield: Seed yield was not significantly affected by the planting methods (Table 2). Seed yield of fodder maize was maximum at 150 kg N/ha (63.3 q/ha), which was significantly higher than 125 kg N/ha, 100 kg N/ha and control (21.0 q/ha) which was 16.3, 28.4 and 66.8 per cent higher as compared to 125, 100 kg N/ha and control, respectively. Singh *et al.* (2003) also observed a significant increase in grain yield at high N levels. Planting methods had no significant influence on stover yield. BP showed fairly better stover yield than CT and ZT. It produced 9.5 and 10.3 per cent higher stover yield as compared to CT and ZT. Bed planted crop had better growth and more dry matter accumulation resulting in higher stover yield than the other methods of sowing. Maximum stover yield was recorded under 150 kg N/ha which was significantly better than 100 kg N/ha and control, but at par with 125 kg N/ha. Chaudry and Jamil (1998) revealed that stover yield increases with increasing nitrogen rate. The reduction of stover yield might be associated with lower plant height and lower internodes growth.

Maize fodder gave the similar seed yield with the ZT, CT and BP. CT and BP requires intensive tillage for sowing of crop and it will enhance the cost of cultivation but not seed yield and also delay the sowing due to the seed bed preparation. The application of 150 kg N/ha gave the significantly higher seed yield than all other N levels. Therefore, fodder maize can be sown with ZT for higher seed yield at low cost by skipping the tillage operation at the time of sowing.

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Variability in Limonoid and Oil Content of Neem in Different Eco-Climatic Regions of Rajasthan

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Abstract: The present study deals primarily with oil and limonoids, tree structural features, seed characters among selected 53 plus trees (PTs) of neem Azadirachta *indica* A. Juss) distributed in extreme arid, arid, semi arid and dry sub-humid regions. Due to better rainfall and other favourable environmental conditions, the growth and development of tree structural traits were best in dry sub-humid region. However, it was not same for seed characters, and oil and limonoid content. The progressive increase in seed diameter from dry sub-humid region to extreme arid region indicated presence of bold and better quality seeds as diameter was found to be one of the best seed characteristic for quick selection of better seeds to raise quality seedling for future tree crops having high oil and limonoid contents. Further presence of high concentration of azadirachtin-A (AA), azadirachtin-(AB), nimbin (N) and salinin (S), and as well as oil content in PTs of extreme arid region indicated that adaptability of trees of the spices in a very high thermal environment coupled with very low moisture conditions. Probably such situation influence better synthesis of these compounds. Moreover, production of seeds in high quantum does not necessarily mean that they contain high amount of limonoids.

Key Words: Azadirachtin, Limonoid, Neem, Nimbin, Oil Plus Tree, Salanin

Neem (*Azadirachita indica* A. Juss is an ever green tree that can grow upto 20 m tall. Its spreading branches forms rounded crowns, sometimes up to 10 m in diameter. Neem is rarely leafless and is usually in full foliage even during months of prolonged drought. There are acknowledged to be two varieties of neem; *A. Indica* (Indian neem) and *A. indica* var. siamensis (Thai neem). Indian neem is spread throughout the Indian sub- continent, while Thai neem has a wide natural distribution in Thailand and adjoining countries in south east Asia (Willan *et al.*, 1990). In Indian sub-continent, Indian neem is a highly esteemed tree for the people of the region.

Organic pesticides extracted from neem have attracted the attention of whole world in recent years. The pesticidal properties of neem based formulations are due to the presence of bioactive limonoids such as azadirachtins, nimbin, salinin etc. (Kaushish *et al.*, 2006; Azam *et al.*, 2009). Wide variations are found in reproductive phenology of neem in regional scale (Gupta *et al.*, 2010). It appears that the reproductive phenology have some role in formation of limonoids in neem seeds, the source of oil and limonoids. It is important to understand the regional and habitat variations in limonoid content in neem seeds so that it could be established that limonoid content especially AA, AB, N and S is influenced by eco-climatic conditions. The present paper discusses the vaiations in oil and limonoids (AA, AB, N, S) contents in seeds of PTs of neem in different eco-climatic regions of Rajasthan, the area wise largest state of India.

MATERIAL AND METHODS

Primarily based on rainfall patterns, Rajasthan state has four distinct eco-climatic regions. The extreme western part which receives less than average annual rainfall of 200 mm is categorized as extreme arid. A large region which receives rainfall between 200 mm and 350 mm is categorized as arid. Between arid and dry sub-humid region lies a tract which is categorized as semi- arid region (average annual rainfall between 350 mm and 675 mm). Eastern and south eastern part, which receives more than 675 mm rainfall is categorized as dry sub-humid region. Arid Intensive survey was conducted during 2000-2001 under national network on integrated development of neem project in four regions to identify the PTs following the method given by Tewari *et al.* (2001) in which tree height, straight bole length and diameter at breast height (DBH) i.e. 1.37 m above the ground were taken as criteria for selection. In this way 100 candidate plus trees (CPTs) were identified (extreme arid = 14, arid = 38, semi arid = 29, dry sub humid = 19). The CPTs which produced more than 17 kg of seeds were selected as PTs. In this way total 53 PTs were selected of which extreme arid had 8, arid 20, semi arid 15 and dry sub humid 10 (Table 1). All the PTs were registered with National

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Table 1. Details of Plus Trees (PT's) identified from natural stands of *A. indica*

CPT's	IC. No.	Place of collection	Latitude (N)-Longitude(E)
		Extreme arid	
JS-1	268494	15 km NE of Pokaran, Phalodi road, Jaisalmer	26°55′-71°58′
JS-4	268498	2 km NE of Chandan, RRS, CAZRI	do-do
JS-7	268500	-do-	do-do
JS-10	268502	RRS,CAZRI campus, Jaisalmer	do- 70°57′
BR-1	251592	BSF campus, Barmer	25°45′-71°25′
BR-2	251593	-do-	do-do
BR-4	268524	5 km NE of Balotra, Barmer district	25°49′-72°21′
BR-9	251596	Near Nakoda Temple, Balotra, Barmer district	do-do
		Arid	
JD-7	251544	Silva nursery, CAZRI campus, Jodhpur	26°18′-73°04′
JD-8	268485	-do-	do-do
JD-10	268486	Agrostology Block, CAZRI campus, Jodhpur	do-do
JD-11	251548	-do-	do-do
JD-12	251549	-do-	do-do
JD-13	251550	Botanical garden, CAZRI campus, Jodhpur	do-do
JD-15	251552	-do-	do-do
JD-16	251553	-do-	do-do
JD-18	251555	Silva nursery, CAZRI campus, Jodhpur	do-do
JD-20	268493	-do-	do-do
BL-1	251597	5 km NW of Pipad city, Jodhpur district	26°11′-73°42′
BL-2	251598	3 km NW of Bilara town, Jodhpur district	do-do
BL-3	251599	-do-	do-do
MN-1	268512	Forest nursery, Mandore Garden, Jodhpur	26°23′-73°04′
MN-2	251639	-do-	-do-do
MN-3	268514	-do-	do- do
MN-4	268515	Mandore Garden, Jodhpur	26°23′-73°04′
MN-5	251642	Mandore Garden, Jodhpur	do-do
MN-6	251643	Crematory entrance, Mandore Garden, Jodhpur	do-do
MN-7	251644	-do-	do-do
		Semi arid	
JP-3	251652	2 Km SW from Sanganer, Tonk road, Jaipur	26°55′-75°52′
JP-9	251657	-do-	do-do
JP-17	251987	10 km NW of Jaipur, Sikar road, Jaipur	do- 75°50′
UD-1	268541	Gulab Bagh, Udaipur	24°38′-73°33′
UD-4	268545	RCA campus, Udaipur	do-do
UD-9	251584	Eklingji, Udaipur	24°44′ -do-
UD-10	251585	Jang ki Bari, Sukhadia University, Udaipur	24°38′ -do-
CT-1	251568	Near Vijay Stambh, Chittorgarh	24°54′-74°42′
CT-4	268517	Dam side, Chittorgarh	do-do
CT-7	268524	7 km. SE of Nimbahera, Chittorgarh road, Chittorgarh	24°37′-74°45′
CT-8	268525	15 km SE of Kapasan, Chittorgarh road, Chittorgarh	24°46′-74°43′
RJ-1	268546	10 km NW of Kankroli, Rajsamand district	25°02′-73°59′
RJ-5	251589	Near Rajsamand lake, Rajsamand	-do-do
RJ-7	251590	Kumbhalgarh forest range, Desuri, Pali district	25°11′-73°35′
RJ-8	251591	-do-	do-do
		Dry Sub humid	
DG-1	251623	5 km SW of Aspur	23°58′-74°05′
DG-2	251624	10 km SW of Aspur	23°58′-74°06′
DG-6	251625	6 km NW from Dungarpur, Dungarpur	23°50′-73°50′
DG-7	251626	15 km SW of Sagwara, Banswara road, Dungarpur	23°31′-74°05′
DG-9	251628	-do-	-do-do
BW-2	251607	ARS, Banswara	23°30′-74°24′
BW-3	251608	-do-	do-do
BW-5	251609	-do-	do-do
BW-8	251610	-do-	do-do
BW-10	268554	8 km NE of Banswara	do-do

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Bureau of Plant Genetic Resources (NBPGR), New Delhi, where they were given specific IC numbers. These PTs were marked with permanent iron plates having both locally given and as well as IC numbers.

During last week of June and first week July, 2010 when trees were laden with fruits, selected PTs were revisited and 2.5-3.0 kg fruits were collected from individual PTs. The collected fruits were brought to the laboratory. There they were depulped and washed to obtain the pure seed. These seeds of individual PT were dried in shade. From each PT a sample of 250 g dried seeds were taken for further study. First seed characterization viz., 100-seed weight, seed length and seed diameter were measured randomly by standard procedure. After recording said observations, sample seeds of individual PT were broken very carefully by a wooden hammer to obtain kernels. The kernels obtained so were used to determine number of kernels/100 seeds and weight of 100-kernels separately for individual plus tree (PT). Known quantity (10 g) of kernels was ground in an electric mixture for individual PT to determine oil and limonoid viz., AA, AB, N and S.

Seed characters viz.100- seed weight, seed length, seed diameter, number of kernel/100 seeds and weight of 100-kernels were determined following standard procedure. Seed samples of individual PT were packed with an local identity tag in muslin bags. Oil content from seed kernels were extracted through soxhlet method (%v/w) and limonoids i.e. AA, AB, N and S were analyzed using standard HPLC procedure with known operating conditions (Rengasamy *et al.*, 1993). For computing region wise oil and limonoids content values obtained were averaged across all PTs in each eco-climatic region.

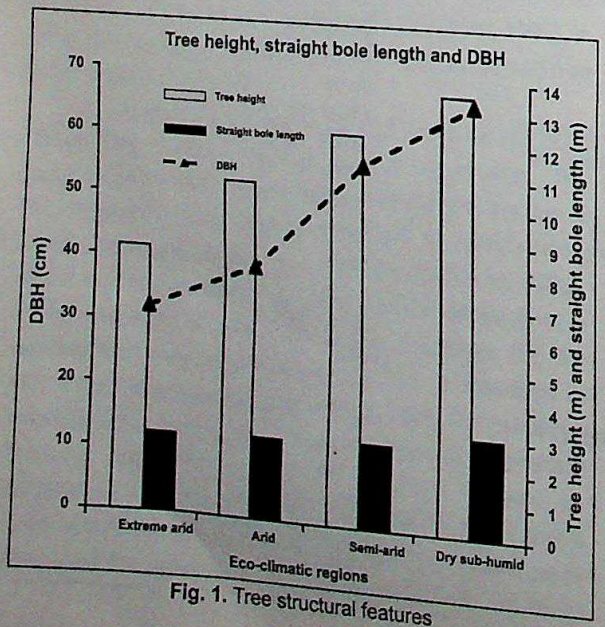

Fig. 1. Tree structural features

RESULTS AND DISCUSSION

Structural features and seed characteristics: Wide variations were recorded in tree structural features. Among individual PT in entire study region, the tree height was maximum for PT, UD-1 and minimum in PT, JD-1. Similarly, straight bole length exhibited marked variation with maximum being observed for PT, BW-10 and minimum for UD-10. Wide variations were observed in seed related characteristics. Seed yield was maximum in PT, UD-1 and minimum in PT, JS-7. 100-seed weight was maximum in PT, DG-7 and minimum in PT, JS-1. Seed length was found to be maximum in PT, JD-10 and minimum in PT, JP-17. Seed diameter was highest in PT, BR-9 and lowest in PT, RJ-8. Number of kernel/100 seeds was maximum in PT, JS-10 and minimum in PT, MN-7. Weight of 100-kernels was highest in PT, DG-7 and lowest in PT, DG-6. On an average across each region tree height, straight bole length and DBH exhibited a progressive increase from extreme arid to dry sub-humid region (Fig. 1), However, no such trend was observed for seed related characters.

On an average across all the PTs in a particular region, total seed yield exhibited a progressive increase (Table 2) from extreme arid to dry sub-humid region. However, mean 100-seeds weight was found to be maximum for PTs of semi arid region and minimum for PTs of extreme arid region.

On an average across the PTs of particular region though no trend was found for average seed length, interestingly seed diameter exhibited a progressive increase from extreme arid to dry sub-humid region. There was not much difference in average number of kernel/100 seeds in different eco-climatic regions. More or less similar trend was observed for weight of 100-kernels (Fig.2).

Oil and limonoid contents: Oil and limonoid contents exhibited wide variations from individual to individual PTs when the entire study region was considered. Oil content was minimum in PT, CT-4 and maximum in MN-2. AA was found to be minimum in BW-8 and maximum in BR-9. Similarly for AB, lowest value was found in PT, DG-6 and highest in BR-1. DG-6 had lowest N content and BR-2 had highest. S was found to be minimum in BW-5 and maximum in JS-10.When the value of all said parameters were averaged across individuals in a particular eco-climatic region, it was observed that oil content progressively increased from dry sub- humid to extreme arid region. It was very interesting that on an average across the individual PTs, values of limonoid contents (AA, AB, N and S) also exhibited a systematic increase from dry sub-humid to extreme arid region. Data indicated that average oil content was 5.2 percent higher in extreme arid region as compared to dry

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Table 2. Summary of structural features, seed characteristics and oil and limonoid contents of PTs in different eco-climatic regions of Rajasthan

Particular	Extreme arid			Arid			Semi arid			Dry sub-humid		
	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)
Tree characters												
Tree height (m)	7.25(BR 9)-10.20 (JS4)	8.30	10.79	7.20(JD 11)-12.43(JD 10)	10.53	13.89	7.53(RJ 5)-16.92(UD1)	12.22	19.77	8.00(DG 9)-16.8(DG 1)	13.57	18.89
Straight bole length (m)	1.90(BR1)-3.37(BR9)	2.46	20.17	1.90(JD 20)-3.73 (JD 10)	2.54	18.45	1.80(UD 10)-4.07(JP 3)	2.63	21.70	2.00(DG 9)-4.40 (BW 10)	3.03	20.38
DBH (cm)	25.60(BR2)-37.00(BR9)	32.01	12.98	22.61(JD 11)-53.46(JD10)	39.21	21.28	2.6(UD 10)-107.00(JP 3)	56.40	41.02	40.81(DG9)-101.43(BW (10)	66.52	36.68
Seed characters												
Seed yield (kg tree^{-1})	16.0(JS 7)-27.0 (BR 9)	21.00	17.26	16.0(JD 11)-41.0 (MN 1)	25.4	13.51	16.0(CT 7)-49.0 (UD 1)	28.07	37.28	20.0(DG 9)-39.0 (DG 7)	29.37	20.12
100- seed wt (g)	11.67 (JS 1)-14.53 (JS 10)	12.90	9.29	14.15(JD 7)-22.01(MN 3)	17.56	11.48	14.36(RJ 1)-20.19 (JP 3)	18.57	7.93	12.41(BW 8)-23.73 (DG 7)	16.39	22.83
Seed length (cm)	0.93(BR 9)-1.20 (JS10)	1.03	9.29	0.95(MN 7)-1.42 (JD 10)	1.17	11.48	0.91(JP 9)-1.29 (UD 1)	1.12	10.60	0.94(BW 8)-1.28(DG 7)	1.07	11.11
Seed diameter (cm)	0.59(JS 1)-0.78 (BR 9)	0.66	9.31	0.55 (JD 10)-0.66 (MN 3)	0.60	5.54	0.49(RJ 8)-0.62(JP 3)	0.56	7.21	0.49(DG 6)-0.61(DG7)	0.55	7.23
No. of kernel/100 seeds	102 (JS 7)-115 (JS 10)	109	4.66	79(MN 7)-112 (JD 7)	103	7.73	90(JP 9)-109(CT 4)	100	5.18	96(DG 1)-108(BW 5)	102	3.97
Wt. of 100 kernels (g)	8.38(BR 9)-10.36 (JS 10)	9.08	6.92	7.73(MN 1)-9.74 (BL 2)	8.82	6.90	7.65(RJ 1)-10.24 (RJ 5)	8.62	8.19	6.94(DG 6)-10.94 (DG 7)	9.01	11.96
Oil and limonoids												
Oil percent (%v/w)	38.95 (BR9)-41.38 (BR 20	40.1	2.26	36.62(JD 8)-45.14 (MN 2)	41.87	5.71	34.79(CT 4)-43.90 (JP 9)	40.88	5.92	36.38(BW 5)-42.35 (BW 10)	38.10	4.38
Azadirachtin A (mg kg^{-1})	1210(JS 1)-1377 (BR 9)	1312.25	4.42	1190(BL 3)-1321 (MN 4)	1246.55	3.42	1107(RJ 5, UD 10)-1272(JP 17)	1175.13	4.34	1020 (BW 8)-1201(BW 3)	1092.2	5.39
Azadirachtin B (mg kg^{-1})	402(JS 1)-482 (BR 9)	444.13	7.25	357(MN7)-410 (JD 20)	389.8	3.83	297(RJ 7)-384(JP 9)	327.93	8.84	271(DG 6)-319 (BW 2)	296.8	5.05
Nimbin (mg kg^{-1})	1181 (BR 9)-1261(BR 2)	1213	2.30	1070(JD 10)-1201 (JD 8)	1112.9	3.47	1020 (RJ 7,8)-1121 (UD 1)	1070	3.23	972(DG 6)-1072 (DG 9)	1014	2.91
Salinin (mg kg^{-1})	1207(JS 1)-1272(JS 10)	1226.63	2.04	1102 (JD 13)-1222 (JD 7)	1163.25	3.70	1067 (CT 1)-1178(JP 17)	1090	2.90	957(BW 5)-1101(DG 7)	1034.7	5.12

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sub-humid region. Among the limonoids, AB was 49.63 percent higher in extreme arid region in comparison to dry sub-humid region. In the rest of the limonoids, this systematic progressive increase ranged from 18.54 percent in case of S to 20.15 per cent in case of AA (Fig.3).

The low coefficient of variation for oil and limonoids content in different eco-climatic region of Rajasthan state, India indicated that oil and limonoid content in particular eco-climatic region has very higher degree of uniformity. From the observations it can be safely concluded that concentration of limonoid contents in neem seeds had great impact of environmental conditions of different eco-climatic region. Rengasamy and Parmer (1995) reported that eco-type belonging to arid ecosystem had high AA than those from sub-humid regions.

Interrelationship among tree structural feature, seed characteristics and, oil and limonoid contents: Through considering group of PTs of different eco-climatic region certain set of ranking of characters were observed, however when all individual PTs irrespective of eco-climatic regions were considered, no one had very clear cut ranking as far as tree structural traits and seed characteristics are concerned. Oil and limonoid content in PTs definitely showed clear cut trends in different eco-climatic regions. These observations demanded to study of the interrelationships among various characters studied. As would be expected auto correlations were found for within the group of tree structural characters, seed characters, and oil and limonoid contents in the seed kernel.

Of the possible 81 characters combinations 33 found to be significantly positively correlated and 19 were observed to be significantly negatively correlated. Tree height was found to be significantly positively correlated with straight bole length, DBH and 100-seed weight and total seed yield. DBH was found to be significantly positively correlated with straight bole length, 100-seed weight as well as total seed yield. Straight bole length didn't show any relation with total seed yield, and seed characters, and oil and limonoid content.

Seed diameter was found to be positively and significantly correlated with number of kernels/100 seeds, weight of 100-kernels, AA, AB, N and S. Oil percent was found to be positively correlated with seed length but no significant correlation could be found with other seed characters, except in case of N, where oil percent was significantly and positively correlated. Number of kernels/100 seeds was found to be positively and significantly correlated with weight of 100-kernels, AA, AB, N and S. As expected AA, AB, N and S exhibited significantly positive correlation among themselves. There are many tree structural characters showed some kind of relationship with oil and limonoid content but such relationship do not have any practical value.

Most interesting feature of this correlation matrix was that total seed yield was significantly negative with AA, AB, N and S contents (Table 3). Even oil content was negatively correlated with total seed yield though not significant. With exception of seed length, other important seed related characters exhibited negative correlation though not significant. This indicated that high seed yield does not necessarily mean better quality of seeds.

In general, oil was found in higher quantum in drier eco-climatic conditions, as quantity of oil extracted from seeds of arid and extreme and eco-climatic region was

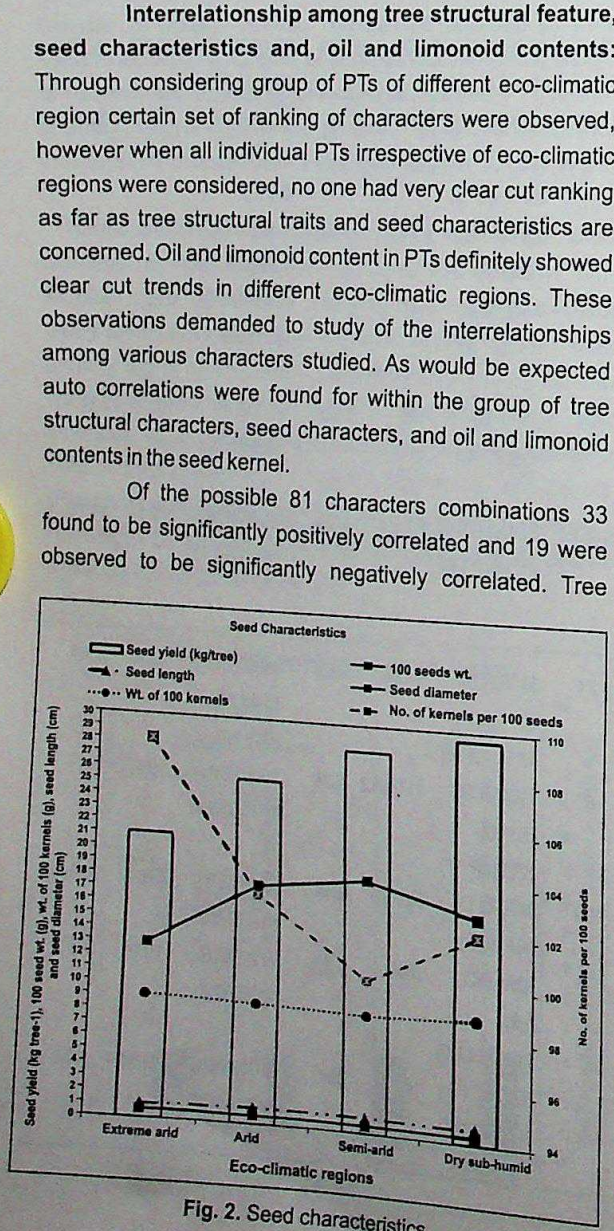

Fig. 2. Seed characteristics

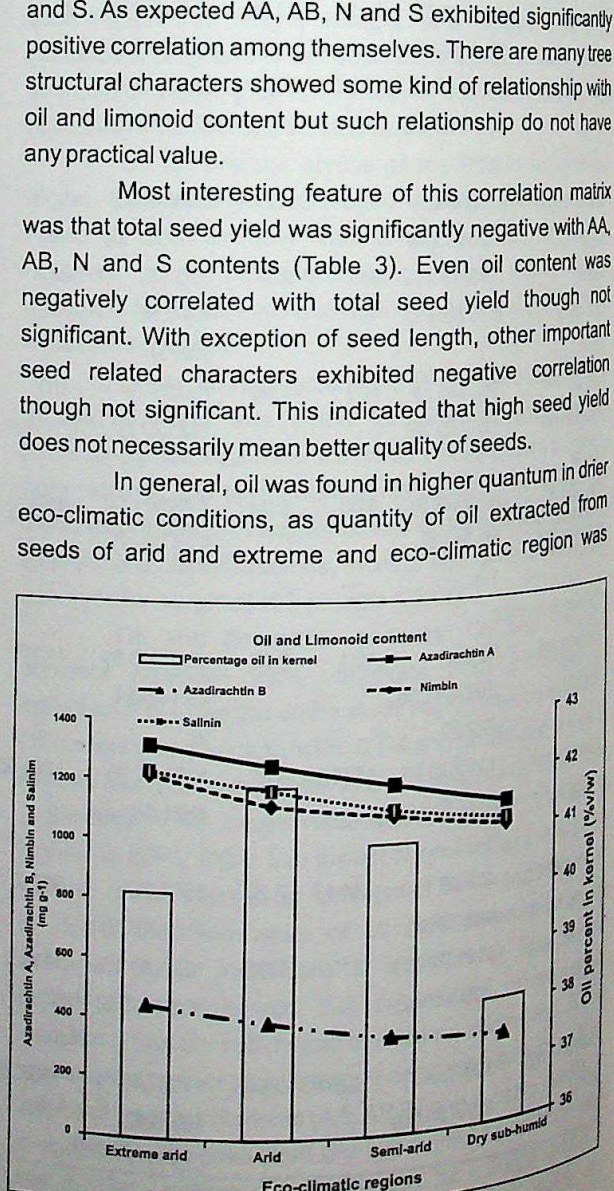

Fig. 3. Oil and limonoid content

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Table 3. Interrelationship among tree structural feature, seed characteristics and, oil and limonoid content in entire study area

Character	Tree height	Straight bole length	DBH	100 - seed wt.	Seed length	Seed diameter	No. of kernel/ 100 seed	Wt. of 100 kernels	Oil percent	AA	AB	N	S	Seed yield
Tree height	1	0.503**	0.770**	0.466**	0.098	-0.440**	-0.343*	0.007	-0.124	-0.556**	-0.529**	-0.566**	-0.534**	0.531**
Straight bole length		1	0.648**	0.196	0.088	-0.072	0.139	0.191	0.021	-0.124	-0.136	-0.224	-0.270*	0.255
DBH			1	0.342*	0.065	-0.316*	-0.285*	0.055	-0.006	-0.413**	-0.410**	-0.459**	-0.446**	0.417**
100- seed wt.				1	0.404**	-0.117	-0.108	0.161	-0.126	-0.271*	-0.266	-0.400**	-0.296*	0.317*
Seed length					1	0.094	0.159	0.100	0.250**	0.017	0.064	-.054	0.088	0.426**
Seed diameter						1	0.562**	0.298*	0.070	0.528**	0.678**	0.626**	0.553**	-0.154
No. of kernel/ 100 seed							1	0.349*	-0.072	0.311*	0.408**	0.416**	0.325*	-0.134
Wt. of 100 kernels								1	-0.194	-0.065	0.097	0.094	0.016	-0.021
Oil per cent									1	0.364**	0.292*	0.136	0.285*	-0.027
AA										1	0.785**	0.733**	0.776**	-0.325*
AB											1	0.814**	0.794**	-0.258
N												1	0.799**	-.0306*
S													1	-0.385**
Seed yield														1

relatively higher than oil found in seeds of dry sub-humid and semi-arid eco-climatic region. Our findings in conformity the results obtained by Tewari *et al*. (2007) who ascribed it to site x environment interaction.

Production of secondary metabolite is governed by both genetic and environmental factors (Kamarainen *et al*., 2003). In a region specific study, large variations in azadirachtin content (7525-2895 mg kg^{-1}) has been reported in neem kernels of different ecotypes in Tamil Nadu (Kumar *et al*., 1995).

Rajasthan the largest state of India is spread over an area of 3,42,239 km^2. The state has four different eco-climatic regions with a total annual average rainfall gradient extending from 200 to 900 mm. Neem grows profusely in entire state except hilly tract (altitude > 350m). In present investigation, tree structure, seed characteristics and major limonoids of 53 PTs were studied precisely, as the work on erstwhile 'National Network on Integrated Development of Neem' project ended with selection, location, positioning, marking and description of identified PTs on the basis of tree architecture and fruit/seed production potential. Analysis of limonoids was done at some centres but that too very unsystematically. Present study clearly indicated that on an average across the PTs total seed yield/PT of dry sub-humid region was 29.37 kg which was 4.4 %, 13.7 %; and 28.5 % higher than that of semi arid, arid and extreme arid region, respectively. Contrary to this, quantity of AA, AB, S and N showed a just a reverse trend. The progressive increase in seed diameter from dry sub-humid region to extreme arid region indicated presence of bold and better quality of seed as seed diameter (on an average across individual PT of particular region) was found to be one of the best seed characteristics for selection of seeds to raise large scale nursery for having quality seedling for future tree crops having high azadirachtin content (Kaushish, 2006).

Neem seeds having higher quantity of limonoids must be given preference for nursery raising so the future plantations of neem in any form yield seeds of high limonoids contents. The presence of higher concentration of AA, AB, N and as well as oil content in PTs of extreme arid region indicated that adaptability of trees of the species in a very high thermal environment coupled with very low moisture regime should have some influence of reproductive phenophases at some point (Azam *et al*., 2009) which in turn perhaps enhance the synthesis of these compounds. Infact, this is one probability, but to establish the facts presented in the study require more precise eco-physiological investigations. However, present study clearly proved that production of high quantity of seed does not necessarily mean the production of quality seed material especially, in context of limonoids.

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Integrated Pest Management Strategies for Sustainable Transgenic Cotton Pest Management in Punjab

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Abstract: Integrated pest management (IPM) strategies for the management of sucking insect pests were disseminated in 12 villages of three districts of Punjab during 2010. Three non-IPM villages adjoining to IPM villages were kept as check for comparing the impact. The impact of adoption of IPM strategies led to reduction in the population of mealybug in IPM villages as compared to non-IPM villages. The mean population of jassid per three leaves varied from 0.21 to 1.23 in IPM villages and 0.91 to 2.35 in non-IPM villages. Whitefly population per three leaves varied from 0.38 to 3.05 in IPM villages and 1.58 to 7.30 in non-IPM villages. Population of natural enemies including spiders, predatory bugs, ladybird beetle varied from 0.11 to 1.61 per plant in IPM villages. The impact of dissemination of IPM strategies resulted in the reduction in number of spray in IPM villages (39.73%) over non-IPM villages. The reduction in cost of spray in IPM villages was 32.98 per cent over non-IPM. The average cost of cultivation was Rs. 26112 ha^{-1} in IPM villages, which was comparatively low as compared to non-IPM villages. Average seed cotton yield in IPM villages was 2241 kg ha^{-1} in comparison to non-IPM villages (1864 kg ha^{-1}). The average net return in IPM villages was Rs. 68005 ha^{-1}, which was Rs. 16697 more than non-IPM villages.

Key Words: Bt cotton, Sucking insect-pests, IPM, Non-IPM, Economics

Cotton (*Gossypium* sp.) is a major field crop in many countries, constituting a valuable cash crop for many smallholders in developing countries. Cotton, being the most important commercial crop plays a vital role in social and monetary affairs of India. Besides other causes, major in cotton cultivation are biotic stresses due to attack of insect-pests and diseases, which play a significant role in achieving optimum yield potential. At world level, 1326 species of insects harbour cotton plants (Hargreaves, 1948) and in India, 162 insect species have been reported of which nine are of utmost importance inflicting significant losses in yield (Dhaliwal *et al.*, 2004). In Punjab, there has been a change in pest scenario in the last decades. Besides increasing cost of production and environmental problems, the excessive and indiscriminate use of insecticides for the control of these insect-pests has resulted in development of insecticidal resistance, decline in natural enemies population and resurgence of the insect pests like whitefly, *Bemisia tabaci* (Gennadiaus) and jassid, *Amrasca biguttula biguttula* (Ishida). Besides, these, other sucking pests like thrips, *Thrips tabaci* (Lindemann) hitherto occurring during May-June and aphids, *Aphis gossypii* (Glover) at fag end of the crop season are also gaining importance. During 2006, a new sucking pest, mealy bug, *Phenacoccus solenopsis* (Tinsley) appeared in few pockets of Bathinda, Ferozepur and Muktsar districts and caused economic loss (Dhawan *et al.*, 2007). Mealy bug, a minor pest, which was earlier supposed to be suppressed with the use of insecticides attained the pest status. In 2007, this pest wide spread to other parts of the state and became a menace of great challenge for cotton production. Mealybug because of its high reproductive potential, wide host range, powdery/waxy surface of its body and specific feeding behaviour on the apical and lower stem portion of plant is very difficult to control with insecticides only and there is a need of integrated pest management (IPM). Looking into the potential of these insect pests to cause economic losses and sustainability of cotton production it becomes necessary to develop and disseminate management strategies. Keeping in view the above facts, our main emphasis was to disseminate IPM technologies for the management of sucking pests on cotton.

MATERIAL AND METHODS

Twelve villages were adopted for dissemination of IPM strategies for the management of sucking insect pests in three districts viz. Muktsar, Bathinda and Ferozepur in cotton belt of Punjab state during 2010. In each of the three districts, four villages were selected for dissemination of IPM strategies. From Muktsar district villages adopted were Kothemannawala, Bharu, Husner and Butter. In Bathinda district villages adopted were Shekhpura, Bhagwanpura, Lalewala and Nawanpind and in Ferozepur district villages

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adopted were Dharangwala, Roorianwali, Khatwan and Cholara. Three villages adjoining to IPM villages were kept as check and these constituted the non-IPM villages. Bt cotton crop was grown as per recommendation by Punjab Agricultural University, Ludhana (Anonymous, 2009). All the selected villages were regularly visited twice a week from time of sowing till harvesting to disseminate the IPM strategies and to up scale the knowledge of farmers. Awareness campaign on weed eradication, removal of stacks from fields, sowing of barrier crops and other cultural practices were carried out in these villages. Farmers trainings were conducted to aware the farmers about the recommended varieties, fertilizer application and right use of insecticides. Farmers were given knowledge about spray techniques, judicious use of pesticides, ill effects of tank mixtures of pesticides. Farmers were guided about the benefits of recommended pesticides and harmful effects of unrecommended pesticides on cotton crop. Almost 100 per cent farmers adopted spot treatment technology and use of recommended insecticides for the control of mealy bug in adopted villages. At least 50 farmers from each village were selected as a target group for dissemination of IPM strategies.

RESULTS AND DISCUSSION

Impact of IPM Technology

Variety Selection: IPM technology was disseminated in adopted villages in which approximately 3094 ha area was covered under cotton and about 970 farmers followed IPM strategies and impact of technology was seen on sowing time and variety selection and all other agronomic practices. The area under timely sown crop (15th April to 15th May) varied from 74 to 85 per cent and under recommended varieties varied from 65 to 80 per cent (Table 1). There was about 72.50 per cent area under recommended varieties in adopted villages. Maximum area was under recommended varieties like MRC 7031, MRC 7017 and F 6488. Among different villages, maximum area under recommended varieties i.e. 85 per cent was in Cholara village of Ferozepur district.

Incidence of Sucking Insect pests: The population of jassid on cotton in different IPM and non-IPM villages remained below the economic threshold level. The average population of jassid during different meteorological weeks (MW) varied from 0.21 to 1.23 per three leaves in different IPM villages. In non-IPM villages also, the mean population of jassid nymphs was 0.91 to 2.99 per three leaves. However, it was slightly higher than IPM villages in corresponding MW. The mean population of jassid per three leaves was 0.72 in IPM villages as compared to 2.00 in the non-IPM villages. The population of whitefly adults per three leaves varied from 0.38 to 3.05 during different MW in IPM villages. While in non-IPM villages, it varied from 1.58 to 7.30 per three leaves. Higher population of whitefly was recorded during 37th MW in non-IPM villages. The mean population of whitefly per three leaves was 1.83 in IPM villages as compared to 3.46 in non-IPM villages. In case of IPM villages mealybug varied from zero to 0.16 per 2.5 cm of central shoot during different MW. In non-IPM villages, the average population of mealy bug varied from 0.03 to 0.60 per 2.5 cm during different MW. Maximum population was recorded in

Table 1. Area under cotton, number of IPM farmers and sowing pattern in IPM villages

District	Village	Total Area under cotton (ha)	No. of farmers followed IPM	Per cent area under			
				Timely sown (%)	Delayed sown (%)	Recommended varieties (PAU + GEAC*) (%)	Un-recommended varieties (%)
Bathinda	Shekhpura	247.5	96	85	15	65	35
	Bhagwanpura	250	102	79	21	72	28
	Lalewala	274	105	80	20	69	31
	Nawan pind	370	100	83	17	71	29
Ferozepur	Dharangwala	257	80	75	25	72	28
	Roorianwali	285	85	78	22	75	25
	Khatwan	364	68	80	20	79	21
	Cholara	415	61	85	15	70	30
Muktsar	Kothemannawala	105	51	74	26	75	25
	Bharu	167	70	82	18	80	20
	Husner	221	82	80	20	71	29
	Butter	139	70	84	16	71	29
Punjab		3094.00	970.00	80.42	19.58	72.50	27.50

*GEAC-Genetic Engineering Approval Committee

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non-IPM villages and it was found to be 0.60 per 2.5 cm in 31st MW. The average population of mealy bug was less in IPM (0.04) as compared to non-IPM villages (0.19). In case of IPM villages, population of thrips varied from zero to 1.60 per three leaves during different MW (Table 2). In non-IPM villages, the average population of thrips remained 0.17 to 1.65 per three leaves during different MW. The average population of thrips was more in non-IPM (1.00) as compared to IPM villages (0.63).

In Muktsar district, low population of mealybug was recorded in IPM villages throughout the season. However, higher population of mealybug per plant was recorded on weeds growing on wasteland as compared to weeds growing in or around the cotton field in all the villages (Fig. 1). Maximum population was recorded in Butter village on weed on wasteland (0.26) as compared to weed growing in or near the fields (0.14). Similarly, in district Ferozepur, higher population was recorded in Cholara village on weeds growing on wasteland (0.79) as compared to weeds growing in or near the fields (0.45) as shown in Fig 2. Among all the districts maximum population of mealybug was recorded in village Lalewala of district Bathinda (Fig 3) on weeds growing on wasteland (8.26) as compared to weeds growing in or near the fields (3.30).

Table 2. Incidence of Insect-pests and population of natural enemies in cotton (Punjab)

Village	Incidence of insect pest during different meteorological week													
	26th	27th	28th	29th	30th	31s	32nd	33rd	34th	35th	36th	37th	38th	Mean
							Jassid nymphs/ 3 leaves							
IPM	0.25	0.21	0.83	0.98	1.10	1.23	0.87	0.67	0.64	0.82	0.63	0.79	0.36	0.72
Non-IPM	1.27	2.35	0.91	1.65	1.62	2.04	2.20	2.35	2.24	2.07	2.71	2.99	1.62	2.00
							Whitefly adults/ 3 leaves							
IPM	0.52	0.38	1.42	2.33	1.80	2.94	1.73	3.05	1.93	2.85	1.75	2.11	1.03	1.83
Non-IPM	2.40	4.55	1.58	2.69	2.59	3.12	3.10	4.55	2.97	3.54	3.82	7.30	2.83	3.46
							Mealy bug/ 2.5 cm in infested plants							
IPM	0.00	0.01	0.10	0.16	0.01	0.00	0.14	0.00	0.00	0.00	0.02	0.01	0.07	0.04
Non-IPM	0.03	0.04	0.08	0.44	0.40	0.60	0.22	0.04	0.24	0.15	0.07	0.08	0.10	0.19
							Thrips/ 3 leaves							
IPM	0.10	0.10	0.00	0.44	1.60	0.55	1.14	0.55	0.71	1.29	0.39	0.86	0.44	0.63
Non-IPM	1.05	1.05	0.17	0.78	1.03	1.65	1.48	1.05	1.05	1.08	1.03	1.02	0.59	1.00
							Tobacco caterpillar/ plant							
IPM	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.16	0.37	0.10	0.05
Non-IPM	0.13	0.18	0.00	0.00	0.17	0.19	0.14	0.18	0.18	0.83	0.48	1.45	0.10	0.31
							Number of natural enemies/ plant							
IPM	0.17	0.11	0.41	0.50	0.51	0.75	0.99	0.70	0.97	1.01	1.16	1.61	1.12	0.77
Non-IPM	0.05	0.43	0.16	0.43	0.57	0.55	0.65	0.43	0.63	0.47	0.34	0.88	0.16	0.44

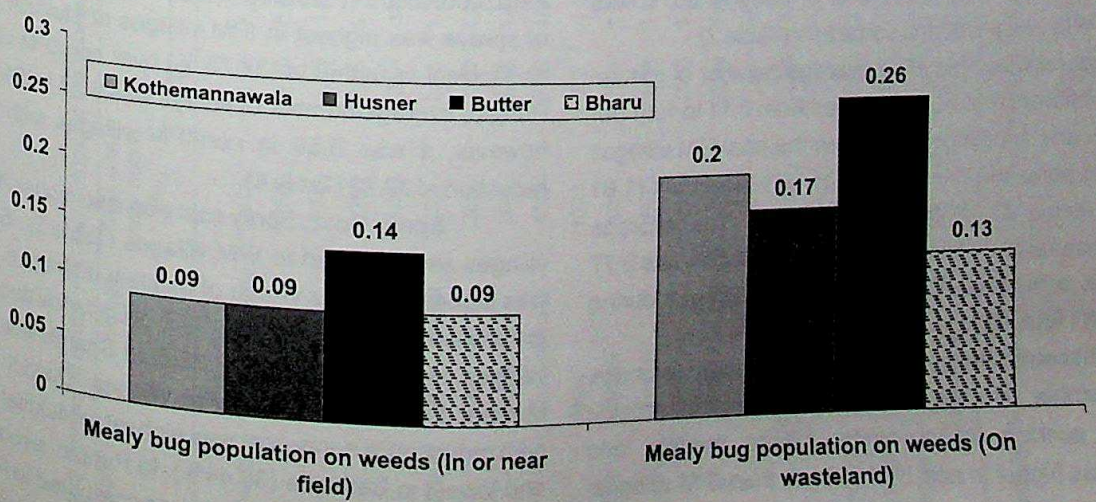

Fig. 1. Mean population of mealy bug in zero mealy bug villages in Muktsar district

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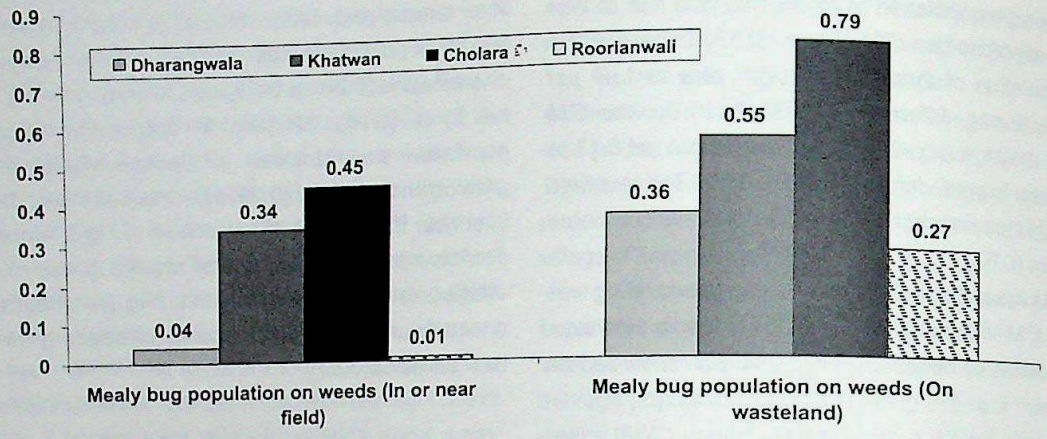

Fig. 2. Mean population of mealy bug in zero mealy bug villages in Ferozepur district

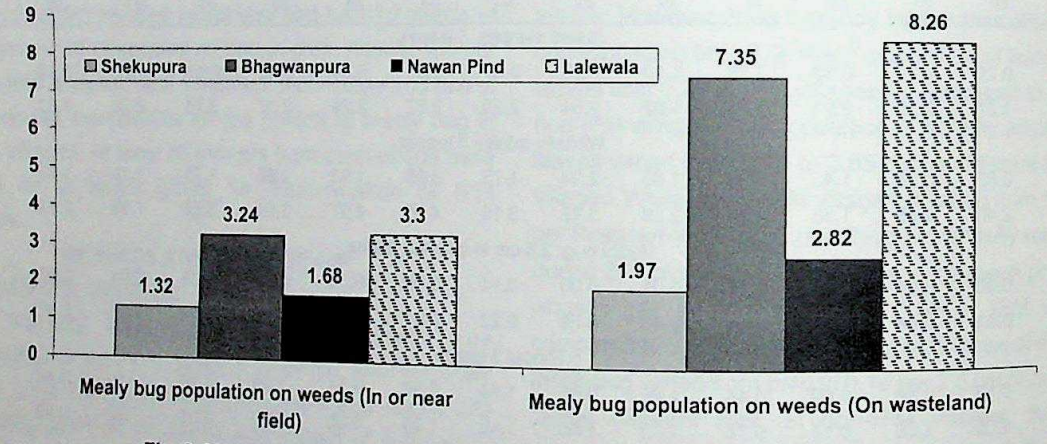

Fig. 3. Mean population of mealy bug in zero mealy bug villages in Bathinda district

Tobacco Caterpillar: Very low incidence of tobacco caterpillar was recorded during different MW. However, maximum incidence of tobacco caterpillar was observed during 37th MW (0.37) in IPM villages and it was 1.45 in non-IPM villages during same MW (Table 2).

Natural Enemies: The average number of natural enemies in different IPM villages varied from 0.11 to 1.61 per plant, which was relatively higher than the non-IPM villages (0.05 to 0.88 per plant). The population was maximum (1.61 per plant) during 37th MW in IPM villages. The average number of natural enemies in different IPM villages was 0.77 per plant as compared to 0.44 in non-IPM villages during different MW (Table 2).

Impact of Dissemination of IPM Strategies on Economics

Number of sprays: Mean number of insecticide sprays for sucking insect pests, foliage feeders and bollworms was higher in non-IPM villages than IPM villages. Among the 12 villages it was highest sprays (4.00 each) in Lalewala and Dharangwala village of Bathinda and Ferozepur, respectively followed by 3.95 sprays in Khatwan village of Ferozepur district under IPM villages. In non-IPM, village number of sprays was 5.91 in Tajjapatti village of Ferozepur district (Table 3). The per cent reduction in number of sprays was highest in IPM villages of Muktsar (42.38%) and lowest in Bathinda (37.73 %) over non-IPM villages. In Punjab, average number of sprays was 3.37 in IPM villages, however, it was 5.58 in non-IPM villages with per cent reduction of 39.73 (Table 4).

Spray Cost: Spray cost was also higher in non-IPM villages as compared to IPM villages (Table 3). Spray cost was highest in Butter village of Muktsar district i.e. Rs. 2233 and lowest in Nava Pind (Rs. 1993) of Bathinda district in IPM villages. However, it was Rs. 3267 in Shamkhera village of Muktsar district under non-IPM villages. District wise, per cent reduction in spray cost was highest in Muktsar (34.43%) and lowest in Bathinda (30.44%). In Punjab, average spray cost was Rs 2123 in IPM villages as compared to Rs 3162 in non-IPM. Per cent reduction of spray cost in IPM villages was

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Table 3. *Impact of cotton IPM technology on the economics and net returns*

District	Village	Total area under cotton (ha)	No. of sprays/ha					Total no. of sprays	Cost of sprays (Rs/ha)	Cost of inputs (Rs//ha)	Cost of farm operations (Rs/ha)	Cost of cultivation (Rs/ha)	Seed cotton Yield (Kg/ha)	Net Profit (Rs/ha)
			W	J	TC	BW	MB							
								IPM						
Bathinda	Bhagwanpura	247.5	1.88	1.20	0.10	0.00	0.00	3.10	2008	7488	18075	25563	2186	66232
	Lelewala	250	2.20	0.80	1.00	0.00	0.00	4.00	2079	8561	18041	26601	2229	67020
	Nava Pind	274	1.65	1.35	0.21	0.00	0.00	3.21	1993	8250	18106	26356	2160	64378
	Sekhpura	370	2.15	1.10	0.10	0.00	0.00	3.35	2139	8005	18057	26063	2246	68275
	Mean	1141	2.0	1.1	0.4	0.0	0.0	3.4	2055	8076	18069	26145	2205	66476
Ferozepur	Dharangwala	257	2.48	1.30	0.30	0.00	0.00	4.00	2107	8443	17923	26366	2262	68672
	Cholara	285	2.00	1.00	0.00	0.00	0.00	3.00	2111	9061	17663	26527	2189	65223
	Khatwan	364	2.48	1.42	0.15	0.00	0.00	3.95	2193	9166	19632	28798	2392	71697
	Ruharianwali	415	2.15	1.35	0.00	0.00	0.00	3.50	2277	9178	18619	27797	2476	76207
	Mean	1321	2.3	1.3	0.1	0.0	0.0	3.6	2172	8962	18459	27372	2329	70449
Muktsar	Bharu	105	2.00	1.00	0.12	0.00	0.00	3.12	2108	8521	16021	24542	2213	68422
	Butter	167	1.98	1.02	0.10	0.00	0.00	3.10	2233	8876	16976	25853	2165	64691
	Husnar	221	2.00	1.00	0.00	0.00	0.00	3.00	2093	8279	16057	24335	2225	69106
	Kothe Manawale	139	2.00	1.15	0.15	0.00	0.00	3.30	2133	8561	15907	24468	2157	66137
	Mean	632	2.0	1.0	0.1	0.0	0.0	3.1	2142	8559	16240	24799	2190	67089
	Total /Mean	3094	2.08	1.14	0.19	0	0	3.37	2123	8532	17590	26105	2242	68005
								Non IPM						
Bathinda	Dyalpura	366	2.20	2.77	0.49	0.00	0.00	5.46	2953	10060	16895	26955	1866	51406
Ferozepur	Tajjapatti	449	2.22	3.31	0.38	0.00	0.00	5.91	3266	11264	16114	27377	1896	52273
Muktsar	Sham Khera	374	2.08	2.80	0.51	0.00	0.00	5.38	3267	10418	16227	26646	1831	50244
	Total /Mean	1191	2.17	2.96	0.46	0.00	0.00	5.58	3162	10580	16412	26992	1864	51307

W- Whitefly, J- Jassid, TC- Tobacco caterpillar, BW- Bollworms and MB- Mealybug

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Table 4. Per cent reduction in sprays, spray cost, cost of cultivation, yield and net profit over non-IPM

District	Number of sprays			Spray cost (Rs/ha)			Cost of cultivation (Rs/ha)			Yield (kg/ha)			Net profit		Additional profit	Additional Profit (%)
	IPM	Non IPM	% reduction	IPM	Non IPM	% reduction	IPM	Non IPM	% reduction	IPM	Non IPM	% reduction	IPM	Non IPM		
Bathinda	3.4	5.46	37.73	2055	2953	30.44	26145	26955	3.05	2205	1866	15.37	66476	51406	15070	22.66
Ferozepur	3.6	5.91	39.09	2172	3266	33.49	27372	27377	0.01	2329	1896	18.59	70449	52273	18176	25.80
Muktsar	3.1	5.38	42.38	2142	3267	34.43	24799	26646	6.93	2190	1831	16.39	67089	50244	16845	25.10
Punjab	3.37	5.58	39.73	2123	3162	32.86	26105	26992	3.28	2241	1864	16.78	68004	41307	16697	24.52

32.98 over non-IPM villages (Table 4).

Cost of inputs: Average cost of inputs was higher in non-IPM villages (Rs/ha 10580) as compared to IPM villages (Rs/ha 8532). Village wise it was highest (Rs. 9178 ha^{-1}) in IPM village Ruhianwali of Ferozepur district as compared to Rs. 11264 ha^{-1} in non-IPM village, Tajjapatti of the same district (Table 3).

Cost of cultivation: The cost of cultivation was higher in non-IPM villages than IPM villages (Table 3). In Punjab, it was Rs 26105 ha^{-1} in IPM villages as compared to Rs. 26992 ha^{-1} in non-IPM. The per cent reduction in cost of cultivation was 3.28.

Seed cotton Yield: Seed cotton yield was higher in IPM villages than non-IPM villages. Among IPM villages, it was highest in Ruhianwali village (2476 kg ha^{-1}). However, it was 1896 kg ha^{-1} in Tajja patti village of Ferozepur district under non-IPM villages (Table 3). District wise, it was highest in Ferozepur district (2329 kg ha^{-1}) followed by Bathinda and Muktsar (2205 & 2190). Per cent increase in yield of IPM villages over non-IPM villages was highest in Ferozepur district (18.59). In Punjab, average yield of IPM farmers was 2241 kg ha^{-1} as compared to 1864 kg ha^{-1} of non-IPM farmers. Per cent increase in seed cotton yield in IPM farmer was 16.78.

Net profit: Net profit was higher in IPM villages than non-IPM villages (Table 3). It was highest in Ruharianwali village of Ferozepur district (Rs. 76207 ha^{-1}). In non-IPM villages, it was as low as Rs. 51406 ha^{-1} in Dyalpura village of Bathinda district. Per cent increase in net profit (Table 4) was highest in Ferozepur district (25.80%) and lowest in Bathinda district (22.66%). In Punjab, net profit was Rs 68005 ha^{-1} in IPM villages as compared to Rs 51307 ha^{-1} in non-IPM villages. Addition profit was Rs 16697 ha^{-1}. The per cent increase in additional profit in Punjab was 24.52.

The present findings corroborate with the results of Kranthi *et al.*, (2000), who reported that number of sprays for the control of sucking pests and bollworm complex varied from 8-17 in North India and there was 90 per cent reduction in sprays while seed cotton yield increased up to 59 per cent. Plant protection cost reduced by 25-60 per cent due to impact of the IPM strategies. Similarly, Dhawan *et al.* (2012) reported 40.79 per cent reduction in the number of sprays in IPM villages over non-IPM villages with an additional profit of Rs. 11422 per hectare. Suruli Velu *et al.* (2004) also reported 63 per cent reduction in number of sprays at Coimbatore and Theni districts of Tamil Nadu with the mean of 2.7 in project village as compared to 7.3 in the control villages. With the adoption of IPM strategies, there was less incidence of sucking pests and foliage feeders, higher number of natural

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enemies in IPM villages as compared to non-IPM villages. There was also reduction in number of sprays, spray cost and cost of cultivation and increase in yield and ultimately the net profit.

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Assessment of Economic Threshold Level for Blister Beetles (*Mylabris phalerata*) on Greengram

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Abstract: Blister beetle, *Mylabris phalerata* is a serious pest of short-duration crops like greengram and blackgram. The adult beetles feed gregariously and devours buds and flowers translating in heavy yield reduction. The data on blister beetles density and corresponding loss in pod bearing and grain yield in mungbean varied inversely. The blister beetle density of 1, 2, 3, 4 and 5 beetles per meter row length (mrl) registered decreasing yield trend of 1240, 1120, 950, 750 and 573 kg/ha with corresponding avoidable losses of 9.7, 18.4, 45.4, 58.3 and 68.4 per cent, respectively. The lowest yield was recorded at 8 beetles per mrl (136.7 kg/ha) with avoidable loss of 90.0 per cent, indicating immense damage potential of blister beetles. The economic threshold level of 0.4 blister beetles per mrl is reported for the first time on greengram. The linear regression equation of y = 11.75 – 1.208x and y =1398.0 - 158.6x was set for prediction of loss in pod bearing and yield loss, respectively. The estimated ETL predicted yield loss of 4.7 per cent and loss in pod bearing of 4.2 per cent which validated the established ETL.

Key Words: Blister Beetle, Economic Threshold Level, Greengram

Greengram (*Vigna radiata*: Wilczek), referred as 'Queen of pulses' is the third most important pulse crop of India after chickpea and pigeonpea. Blister beetles, *Mylabris* sp. (Coleoptera: Meloidae) are highly cosmopolitan and reported to occur on pulse crops from tropical Tamil Nadu to temperate regions of Uttar Pradesh (Garg, 1985; Patnaik *et al.*, 1993). In Vidarbha region of Maharashtra, blister beetles were once considered as minor pest, but have assumed a major pest status in recent years, especially on short-duration crops like greengram and blackgram and can inflict huge losses on account of their association with flowering phase (Shende *et al.*, 2013 and Pawar *et al.*, 2014). *Mylabris phalerata* has a wide host range which includes major pulses viz., greengram, cowpea and blackgram. Immense damage potential of 16.8–19.4 flowers per adult per day signifies its economic importance (Dhavan, 2013). Boopathi *et al.* (2009) reported 80 per cent damage of flowers by blister beetles of and yield loss up to 25-30 per cent in greengram.

Adoption of plant protection measure is justified by pest density. The initiation of spray on appearance of pest is costly and may have an adverse effect on the environment. The economic threshold level (ETL) is the best known term and most widely used index in making pest management decisions. The information on crop losses and ETL of blister beetles in greengram is not available, thus, present study was framed to work out this crucial aspect on the basis of adult blister beetles density dependent yield loss.

MATERIAL AND METHODS

An experiment for estimation of ETL of adult blister beetles on greengram was conducted during *Kharif* 2011-12 at Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra). Greengram variety, PKV Green Gold was sown at 30 cm x 10 cm. The crop was raised as per recommended package of practices under pesticide free condition.

The ETL of *M. phalerata* on greengram was worked out on the basis of a cage experiment. The plots were covered with insect proof net of size 1.0 m x 1.8 m x 1.8 m before bud initiation to avoid natural infestation of blister beetles. The cages were set up in such a way that they did not interrupt ventilation and aeration to the growing plants inside. These nylon net cages were erected on iron sticks fixed in four corners. The bottom edges of the nylon nets were inserted into the soil from all sides to check the escape or entry of beetles.

Seven treatments, each comprising of six rows of one meter length, were sown per plot. Field collected assorted population of adult blister beetles were released inside the cage at initiation of flowering at various density differentials (Table 1). Yield of greengram was recorded for a range of beetle densities. The yield loss with every increment of blister beetles was worked out and fitted in linear regression equation. The assessment of losses inflicted by different beetle densities was worked out in terms of number of pods/plant and yield per mrl (g). The yield data was

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extrapolated to per hectare for statistical comparisons by subjecting it to randomized block design by GW Basic program.

The data generated was also utilized for regression equation based validation of blister beetle ETL on greengram. Regression equation between adult blister beetles per mrl and grain yield was worked out to determine the regression coefficient 'b' and the value of gain threshold (GT). Blister beetle density per mrl (X) and grain yield of greengram: q/ha (Y) formed the equation Y= a ± bx. Other approach for validation of ETL was through estimation of economic injury level (Pedigo, 1996). The EIL was enumerated as the ratio between GT and the value of the intercept which gave the incremental yield loss per unit insect.

$$\text{Grain threshold (GT)} = \frac{\text{Cost of plant protection measures (Rs./ha)}}{\text{Market price of the produce (Rs./q)}}$$

Eighty per cent of the yield loss was considered to be avoided with insecticidal treatment. Two applications of methyl parathion dusting @ 20 kg per ha was considered as the cost of plant protection. ETL was set at 75 per cent of EIL (Pedigo, 1996).

RESULTS AND DISCUSSION

I) Estimation of Losses due to Blister Beetle in Greengram:

a. Loss of Pod Bearing: The maximum pods per plant (11.8 pods) were recorded in the control plot where no beetles were released (Table 1). With every increment in the blister beetle count per mrl, reduction in pod bearing was observed. At density of one beetle per mrl, 10.6 pods per plant were recorded with avoidable loss of 10.6 per cent, whereas, two beetles per mrl had 9.6 pods per plant with per cent avoidable loss of 19.3 per cent. Similarly, with each increase in blister beetle density, significant reduction in the pod bearing of greengram was recorded. Pod bearing of 8.1, 6.6 and 5.4 pods per plant with corresponding avoidable loss of 31.5, 44.1 and 54.2 per cent was recorded at beetle densities of 3, 4, and 5 per mrl, respectively. The lowest count of pods was recorded in density of 8 beetles per mrl (2.4 pods) and the per cent avoidable loss of 79.9 per cent, indicating immense damage potential of blister beetles.

b. Prediction of Loss of Pod Bearing: Predicted loss in pod bearing of greengram at various blister beetle densities per mrl (Table 2) was based on regression equation of $y = 11.75 - 1.208x$ with R^2 value of 0.995. The beetle density per mrl and yield per hectare were negatively correlated. From the regression equation, it was evident that one beetle per mrl could cause the apparent pod loss of 1.2 pods per plant. Though, ETL is not available for blister beetle on greengram, generally, review of literature suggests about 5 per cent damage level as ETL. Therefore, as per the derived equation, the established ETL of 0.4 beetles per mrl registered 4.2 per cent loss in pod bearing which is around 5 per cent mark. The next beetle density of 0.5 beetles per mrl translated in pod loss of 5.4 per cent higher than assumed yield loss level of 5 per cent. Thus, ETL of 0.4 beetles per mrl could be treated as an indicator for economic damage beyond which adoption of plant protection measure against blister beetles will be rational.

c. Loss of Grain Yield: The grain yield also varied inversely with beetle density (Table 1). The control plot where no beetles were released registered maximum yield of 1373.3 kg/ha. The higher blister beetle density of 1 and 2 beetles per mrl inflicted 9.7 and 18.4 per cent loss, respectively. Similar trend of decrease in yield due to increasing blister beetle counts was observed in blister beetle abundance of 3, 4 and 5 beetles per mrl with corresponding avoidable yield losses of 45.4, 58.3 and 68.4 per cent, respectively. The lowest grain yield (137 kg/ha) was recorded at 8 beetles per mrl with an avoidable loss of 90.0 per cent. Each of the blister beetle density resulted in statistically significant differences in yield over rest of the densities under evaluation.

Table 1. Effect of different blister beetle densities on pod bearing and yield of greengram

Beetles/mrl	Mean pods per 10 plants	Per cent reduction in pod bearing over control	Grain yield (kg/ha)	Per cent reduction in yield over control
0	118.4	0.0	1373	0.0
1	105.8	10.6	1240	9.7
2	95.5	19.3	1120	18.4
3	81.1	31.5	950	45.4
4	66.2	44.1	750	58.3
5	54.2	54.2	573	68.4
8	23.8	79.9	137	90.0
CD at 5%	2.55		118	
CV %	6.79		22	

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Table 2. Regression equation based estimation of blister beetle density dependent reduction in pod bearing and yield of greengram

Beetles/mrl (x)	(b)	(a)	Pods/plant	Pod bearing loss (pods/plant)	Per cent loss in pod bearing	(b)	(a)	Grain yield (kg/ha)	Yield loss (kg/ha)	Per cent yield loss
0.0	-1.208	11.75	11.8	-	-	-158.6	1398	1398	-	-
0.1	-1.208	11.75	11.6	0.1	1.0	-158.6	1398	1382	15.9	1.1
0.2	-1.208	11.75	11.5	0.2	2.1	-158.6	1398	1366	31.7	2.3
0.3	-1.208	11.75	11.4	0.4	3.1	-158.6	1398	1350	47.6	3.5
0.4	-1.208	11.75	11.3	0.5	4.2	-158.6	1398	1334	63.4	4.7
0.5	-1.208	11.75	11.1	0.6	5.4	-158.6	1398	1318	79.3	5.9
0.6	-1.208	11.75	11.0	0.7	6.5	-158.6	1398	1302	95.2	7.2
0.7	-1.208	11.75	10.9	0.8	7.7	-158.6	1398	1287	111.0	8.5
0.8	-1.208	11.75	10.8	1.0	8.9	-158.6	1398	1271	126.9	9.9
0.9	-1.208	11.75	10.7	1.1	10.1	-158.6	1398	1255	142.7	11.2
1.0	-1.208	11.75	10.5	1.2	11.3	-158.6	1398	1239	158.6	12.6

d. Prediction of Yield Loss: Prediction of yield loss due to blister beetles in greengram was based on regression equation of y = 1398.0 - 158.6x (Table 2) with R^2 value of 0.996. Grain yield varied inversely with beetle density. Predicted grain yield at zero beetle density was 1398 kg/ha, whereas, at one beetle per mrl the predicted yield level was 1239 kg/ha with 12.6 per cent avoidable loss.

II) Assessment of Economic Threshold Level: Plant protection cost of Rs. 2480 for two dustings of methyl parathion (@ Rs. 1240 /dusting/ha) was considered for preventing 80 per cent avoidable loss.

Gain Threshold (GT) =2480/3000 = 0.82 q/ha.

Economic injury level (EIL) = 0.82/1.59 = 0.51 beetles per mrl

Once the population reaches the ETL, chances are good that it will grow to exceed the EIL.

ETL is 75 per cent of EIL = 0.51 x (75/100) = 0.38 beetles per mrl.

Thus, the ETL of blister beetle was established at 0.38 ≈ 0.4 blister beetles/mrl for greengram. Durairaj and Ganapathy (2000) reported that the yield loss was positively correlated with beetle numbers (r= 0.87) and an economic injury level (EIL) of 3 beetles per 10 plants was established at flowering in cowpea. Based on a constant Grain Threshold level, Economic injury level of 7.97 and 7.78 beetles per 50 pigeonpea plants at flowering were enumerated by Durairaj et al. (1998) on pigeonpea cultivars Vamban 1 and ICPL 86012, respectively.

Pawar *et al.* (2013) reported that for effective management of adult blister beetles on greengram, selection of insecticides, the application time and application interval are very crucial. Thus, present study will help to restrict the losses in greengram due to timely application in a cost effective manner.

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Spatial Distribution of Greenhouse Whitefly, *Trialeurodes vaporariorum* (Westwood) in Tomato Under Protected Environment in North-Western Indian Himalaya

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Abstract: Spatial distribution of greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) was determined in summer and autumn crop of tomato under naturally ventilated polyhouse. The population varied from 0.18 to 4.98 adults per leaf in summer crop and was relatively low in autumn crop (0.26 to 1.92 adults per leaf). The dispersion indices namely, variance to mean ratio, David and Moore index of clumping and Iwao's patchiness regression index revealed the population of *T. vaporariorum* in summer crop to have negative binomial distribution, whereas, in autumn crop it followed binomial series. Lewis index, index of dispersion and Morisita's coefficient of dispersion fitted to determine dispersion of greenhouse whitefly showed that in vegetative stage (pre-flowering) in both the cropping seasons, greenhouse whitefly was distributed randomly. However, in reproductive stage (flowering and fruiting stage), distribution was aggregated/ clumped in summer crop and regular/ uniform in autumn crop. Taylor's power law also proved the hypothesis of population dispersion to be aggregated in summer and regular/ uniform in autumn cropping season. The index of patchiness revealed the clumping in greenhouse whitefly being influenced by the environmental factors greatly.

Key Words: Spatial Distribution, *Trialeurodes vaporariorum*, Protected Cultivation, Tomato

The greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), is a serious pest in temperate regions under protected cultivation situations and in field crops where the summers are warm enough. In India, the pest was first recorded from Nilgiri hills of Tamil Nadu on potato and subsequently it has been reported to infest 102 host plants belonging to 36 plant families (Sood and David, 2012). *T. vaporariorum* remained a low density pest in north - western Indian Himalayan region and assumed significance only in late nineties when it posed a threat to the cultivation of some vegetable crops and ornamental plants under protected and field conditions. Presently, it is categorized as the key pest of tomato under protected environment with more incidence in summer crop (Sharma *et al.*, 2006). Understanding the dispersion parameters of pest population helps in devising sampling plan, determining sample size, population modeling for forecasting and pest management interventions. Information on spatial distribution of *T. vaporariorum* under protected environment is scanty. Therefore, present investigations were undertaken to generate information which would be beneficial in planning strategies for the management of *T. vaporariorum* under protected environment.

MATERIALS AND METHODS

The studies were carried out on spatial distribution of greenhouse whitefly during summer and autumn season crop of tomato under naturally ventilated modified quonset polyhouse (size: 250 m^2) at Palampur (1290 m ASL) representing the mid-hill zone of north-western Indian Himalaya. Tomato cultivar Avtar (F_1 hybrid) was raised following all agronomic practices as per the 'Package of Practices for the Vegetable Crops' (Anonymous, 2010) in insecticide free environment. Thirty day old seedlings were transplanted for raising the crop with plant to plant and row to row spacing of 30 x 60 cm, respectively. Tomato plants were trained on two stems by snapping side shoots at regular interval. The crop was artificially infested by releasing about 500 adults of greenhouse whitefly 10 days after transplanting inside the polyhouse nearby the entrance of the polyhouse. The mean temperature and relative humidity in the polyhouse varied between 23.5 - 28.1°C and 45.9 - 77.9 per cent, respectively, during summer crop, whereas, in autumn crop the corresponding values were 12.0 - 25.8°C and 64.5 – 80.3 per cent.

Visual *in-situ* observations were recorded on the number of greenhouse whitefly adults on all fully opened

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leaves starting from top to bottom on every fourth day between 0800-1000 hours. These observations were recorded from 90 randomly selected plants. Mean adult population per leaf was worked out for different dates of sampling. Various indices of dispersion given hereunder were used to work out the spatial distribution of greenhouse whitefly.

Variance to mean ratio (VMR): The simplest approach used for determining the insect distribution was used as:

$$VMR = S^2/\overline{X}$$

$$\text{where, } S^2: \frac{\sum_{i=1}^{n}(Xi-\overline{X})^2}{n-1} : \overline{X} = \frac{1}{n}\sum_{i=1}^{n} Xi$$

The value of VMR is one for 'Poisson' distribution, less than one for binomial and more than one for negative binomial distribution.

Index of clumping of David and Moore (I_{DM})**:** The index of clumping (I_{DM}) was also calculated to confirm the distribution as given hereunder:

$$I_{DM} = \frac{S^2}{\overline{X}} - 1$$

I_{DM} results in value of zero for Poisson, positive value for negative binomial and negative for binomial distribution.

Lewis index was worked out as per formula given hereunder to determine the dispersion of *T. vaporariorum:*

$$\sqrt{\frac{S^2}{\overline{X}}}$$

The value of this index revealed >1 contagious; <1: regular and =1 random distribution.

Index of dispersion (I_D)**:** Distribution pattern was further confirmed by 'Index of Dispersion' which was calculated as follow:

$$I_D = (n-1)\left(\frac{S^2}{\overline{X}}\right)$$

where, I_D = index of dispersion; n = the number of samples

The Z-coefficient of I_D was also worked out to test its significance as

$$Z = \sqrt{2I_D} - \sqrt{(2v-1)}$$

where, v = degree of freedom (*n-1*)

If $1.96 \geq Z \geq -1.96$, the spatial distribution be random, but in case of $Z > 1.96$ and $Z < -1.96$ this parameter becomes aggregated and uniform, respectively.

Morisita's coefficient of dispersion (I_δ)**:** The uneven distribution was calculated by working out the coefficient of dispersion (I_δ) using following equation:

$$I_\delta = \frac{n\sum Xi(Xi-1)}{N(N-1)}$$

where, n = the number of sample units; X_i = the number of individuals in each sample; *N* = total number of individuals in *n* samples

The following large sample test of significance was used to determine whether the sampled population significantly differed from random:

$$Z = \frac{(I_\delta - 1)}{\sqrt{\frac{2}{n\overline{X}^2}}}$$

If $1.96 \geq Z \geq -1.96$, the spatial distribution be random, but in case of $Z > 1.96$ and $Z < -1.96$ this parameter becomes aggregated and regular, respectively.

Lloyd's mean crowding **and** ***Index of patchiness*****:** Mean crowding ($\overline{X}^*$) to indicate the possible effect of mutual interference or competition among individuals was also determined. The sample estimate of mean crowding was calculated as

$$\overline{X}^* = \overline{X} + \left(\frac{S^2}{\overline{X}}\right) - 1$$

To remove the effect of density changes, the patchiness index $\left(\frac{\overline{X}^*}{\overline{X}}\right)$ was worked out. The ratio of mean crowding to mean density known as patchiness index was also worked out. Values of this index being less than one, equal to or larger than one in under-dispersed, random and clumped distribution, respectively. The values >2 suggests that clumping being due to environmental factors as well as insect behavior; whereas < 2 value reveals only environmental factors influencing clumping.

Taylor's power law**:** According to Taylor's power law, population variance (S^2) is proportional to fractional power of the arithmetic mean ($\overline{X}$) The log function of $S^2 = a(\overline{X})^b$ was used in the following form

$$\log S^2 = \log a + b \log (\overline{X})$$

where, a is sampling factor; b is aggregation parameter in which '*a*' is sample size-related scaling factor; slope *b* is index of aggregation which in turn recalls uniform (*b<1*), random (*b=1*) and aggregated (*b>1*) dispersion of a population.

Iwao's patchiness regression index quantifies relationship between mean crowding index ($\overline{x^*}$) and mean ($\overline{X}$) using the following equation:

$$\left(\overline{x^*}\right) = \alpha + \beta\,\overline{X}$$

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where α indicates the tendency to crowding (positive) or dispersion (negative). The constant β is related to the pattern in which an insect utilizes its habitat and is called density contiguousness coefficient and is interpreted in the same manner as *b* of Taylor's power law. The distribution with β >1 corresponds to the negative binomial series and the distribution with β =1 to models of randomly distributed colonies. This hypothesis was used to test the distribution pattern of greenhouse whitefly under protected environment as elaborated by Subramaniam and Arumugam (2006) and Kianpour *et al.* (2010).

RESULTS AND DISCUSSION

A perusal of data revealed that the mean population of *T. vaporariorum* varied from 0.18 to 4.98 and 0.26 to 1.92 adults per leaf during summer and autumn crops of tomato, respectively, being relatively more during summer season (Table 1 and 2). During summer crop, the value of variance to mean ratio (VMR) remained less than unity upto 41 days after transplanting (DAT) (May 6, 2010) depicting the population to follow binomial distribution. For subsequent observations (45 DAT onward; post-flowering period), the population followed the negative binomial distribution (Table 1). This was further confirmed by the index of clumping of David and Moore (I_{DM}) which revealed the values being positive (>0) for 45 DAT in most of the cases, depicting the distribution of *T. vaporariorum* following negative binomial distribution. In autumn crop, the values of variance were less than their corresponding mean values, depicting the regular distribution. The VMR varied between 0.43 to 0.95, showing that *T. vaporariorum* to follow binomial distribution (Table 2). The index of clumping of David and Moore (I_{DM}) also confirmed the binomial distribution of greenhouse whitefly as all the values being negative in autumn season.

The value of index of dispersion (I_D) revealed that the greenhouse whitefly in summer crop followed random distribution from April 16 to May 14, 2010 (pre-flowering stage), except for one on May 6, 2010 (41 DAT). Thereafter, the population trend was aggregated for most of the observations as the resultant values were >1.96. Morisita's coefficient of dispersion (I_δ) and Lewis index also confirmed the greenhouse whitefly population to be distributed randomly in early growth stages and aggregated in the later stages (49 DAT onward) coinciding with reproductive stage in summer crop of tomato. However, in autumn cropping season, the index of dispersion (I_D) for greenhouse whitefly resulted in values varying between $1.96 \geq Z \geq -1.96$, depicting random distribution for most of the sampling dates upto 49 DAT. However, in later stages, greenhouse whitefly population was distributed uniformly for most of the observations. Lewis index resulted in all the values being < 1 depicting that *T. vaporariorum* to be distributed regularly. This hypothesis was also confirmed by Morisita's coefficient of dispersion (I_δ).

In summer season crop, the values of Lloyd's mean crowding ($\overline{x}$) were more than their respective mean values (45 DAT onwards) further confirmed the clumped distribution of *T. vaporariorum* (Table 1). However, in autumn crop, the values of mean crowding were less than their respective mean values established the under dispersed distribution of greenhouse whitefly (Table 2). The Index of patchiness resulted in value varying from 0.05 to 1.37 and 0.03 to 0.96 in summer and autumn season crop, respectively, being < 2 also suggested that the clumping of *T. vaporariorum* ($\overline{x}$) in tomato under protected environment being influenced by environmental factors only.

The hypothesis with respect to differential dispersion pattern of *T. vaporariorum* in two cropping seasons was further confirmed by Iwao's patchiness regression (Table 3). This resulted in the value of α being negative during both cropping seasons depicting the tendency of *T. vaporariorum* population for dispersion. The value of β was positive and more than unity for summer crop (1.1808) and less than unity (0.9373) for autumn crop depicting the negative binomial and positive binomial series of distribution in summer and autumn crop, respectively. Taylor's power law also provided a better fit to the data in summer crop as evidenced by the value of coefficient of determination (R^2=0.9584) (Table 3). The dispersion parameter, b of Taylor's power law was significantly different (P > 0.05, t-test) from unity (1.2020) indicating that the distribution of greenhouse whitefly was aggregated. However, during autumn season, the value of aggregation parameters (b) was less than unity (0.9148) indicating greenhouse whitefly to be uniformly distributed.

Present findings to have aggregated distribution of greenhouse whitefly in summer crop are in line to observations by Liu *et al.* (1993) and Basso *et al.* (2001) who recorded *T. vaporariorum* distribution to be aggregated in different crops grown under greenhouse conditions. Shen and Ren (2007) and Gusmao *et al.* (2005) also observed the same distribution pattern for *Bemisia tabaci* Gennadius. However, in autumn season crop, the distribution was uniform/ regular in contrast to the findings of the earlier workers cited above may be attributed to low population levels observed as compared to summer crop in present studies.

On the basis of various indices incorporated for determining the spatial distribution, it was evident that *T. vaporariorum* in tomato had differential dispersion pattern in

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Table 1. Indices for spatial distribution of greenhouse whitefly in summer crop of tomato under naturally ventilated polyhouse

Crop stage	Sampling date	Crop age (Days)	Mean population/ leaf ($\overline{X}$)	Variance (S^2)	Variance to mean ratio (VMR)	David & Moore's index of clumping(I_{DM})	Lewis Index	Index of dispersion (I_D)	Morisita coefficient of dispersion (I_δ)	Lloyd's mean crowding ($\overline{X}^*$)	Index of Patchiness ($\overline{X}^*/\overline{X}$)
Vegetative stage	April 16	21	0.18	0.15	0.83	-0.17	0.91	-1.14	-1.19	0.01	0.05
	20	25	0.36	0.34	0.97	-0.03	0.98	-0.18	-0.22	0.32	0.91
	24	29	0.34	0.30	0.86	-0.14	0.93	-0.94	-0.97	0.20	0.59
	28	33	0.28	0.27	0.97	-0.03	0.99	-0.14	-0.19	0.25	0.90
	May 2	37	0.66	0.61	0.93	-0.07	0.96	-0.43	-0.47	0.59	0.89
	6	41	1.72	0.88	0.51	-0.49	0.71	-3.78	-3.28	1.23	0.72
Reproductive stage (post flowering stage)	10	45	1.87	2.09	1.12	0.12	1.06	0.83	0.81	1.99	1.07
	14	49	2.42	2.72	1.12	0.12	1.06	0.83	0.82	2.54	1.05
	18	53	3.38	4.57	1.35	0.35	1.16	2.22	2.36	3.73	1.10
	22	57	4.98	7.60	1.53	0.53	1.24	3.18	3.50	5.50	1.11
	26	61	4.13	6.07	1.47	0.47	1.21	2.87	3.12	4.60	1.11
	30	65	3.50	5.33	1.52	0.52	1.23	3.16	3.48	4.02	1.15
	June 3	69	3.26	5.43	1.67	0.67	1.29	3.92	4.44	3.92	1.21
	7	73	3.04	4.96	1.63	0.63	1.28	3.73	4.20	3.68	1.21
	11	77	2.70	4.89	1.81	0.81	1.35	4.64	5.39	3.51	1.30
	15	81	2.39	3.30	1.38	0.38	1.17	2.37	2.53	2.77	1.16
	19	85	2.47	3.33	1.35	0.35	1.16	2.20	2.33	2.82	1.14
	23	89	2.57	3.60	1.40	0.40	1.18	2.49	2.67	2.97	1.16
	27	93	2.54	2.92	1.15	0.15	1.07	1.00	1.00	2.69	1.06
	July1	97	2.12	3.14	1.48	0.48	1.22	2.93	3.21	2.60	1.23
	5	101	2.21	3.29	1.49	0.49	1.22	2.98	3.26	2.70	1.22
	9	105	2.11	3.74	1.77	0.77	1.33	4.45	5.15	2.88	1.37
	13	109	2.16	2.38	1.10	0.10	1.05	0.71	0.69	2.26	1.05

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Table 2. *Indices for spatial distribution of greenhouse whitefly in autumn crop of tomato under naturally ventilated polyhouse*

Crop stage	*Sampling date*	*Crop age (Days)*	*Mean Population/leaf* $(\overline{X})$	*Variance* (S^2)	*Variance to mean* (VMR)	David & Moore's index of clumping(I_{DM})	Lewis Index	Index of dispersion (I_D)	Morisita coefficient of dispersion (I_δ)	Lloyd's mean crowding $(\overline{X}^*)$	Index of Patchiness $(\overline{X}^*/\overline{X})$
Vegetative stage	September 19	21	0.26	0.19	0.75	-0.25	0.87	-1.73	-1.71	0.01	0.03
	23	25	0.73	0.40	0.55	-0.45	0.74	-3.45	-3.06	0.28	0.38
	27	29	0.80	0.57	0.71	-0.29	0.84	-2.08	-1.97	0.51	0.63
	October 1	33	1.12	0.92	0.82	-0.18	0.90	-1.24	-1.22	0.94	0.84
	5	37	1.34	1.01	0.75	-0.25	0.87	-1.71	-1.64	1.10	0.82
	9	41	1.34	1.10	0.82	-0.18	0.91	-1.21	-1.19	1.17	0.87
Reproductive stage *(post flowering stage)*	13	45	1.42	1.03	0.73	-0.27	0.85	-1.93	-1.83	1.15	0.81
	17	49	1.27	1.21	0.95	-0.05	0.98	-0.27	-0.30	1.22	0.96
	21	53	1.38	0.93	0.68	-0.32	0.82	-2.32	-2.15	1.06	0.77
	25	57	1.61	0.85	0.53	-0.47	0.73	-3.63	-10.81	1.14	0.71
	29	61	1.92	1.31	0.68	-0.32	0.83	-2.30	-12.89	1.60	0.83
	November 2	65	1.62	1.02	0.63	-0.37	0.79	-2.70	-10.88	1.25	0.77
	6	69	1.54	1.19	0.77	-0.23	0.88	-1.57	-1.51	1.32	0.85
	10	73	1.54	0.95	0.61	-0.39	0.78	-2.85	-2.58	1.16	0.75
	14	77	1.46	1.06	0.73	-0.27	0.85	-1.92	-1.82	1.18	0.81
	18	81	1.62	1.00	0.62	-0.38	0.79	-2.82	-2.55	1.24	0.76
	22	85	1.59	1.05	0.66	-0.34	0.81	-2.44	-2.25	1.25	0.79
	26	89	1.52	0.75	0.49	-0.51	0.70	-3.96	-3.40	1.01	0.67
	30	93	1.53	0.66	0.43	-0.57	0.65	-4.58	-3.82	0.96	0.63
	December 4	97	1.36	0.68	0.50	-0.50	0.71	-3.85	-3.44	0.86	0.63
	8	101	1.22	0.58	0.47	-0.53	0.69	-4.12	-3.52	0.70	0.57
	12	105	1.23	0.68	0.55	-0.45	0.74	-3.43	-3.03	0.78	0.63
	16	109	1.20	0.75	0.62	-0.38	0.79	-2.78	-2.53	0.82	0.68
	20	113	1.14	0.80	0.70	-0.30	0.84	-2.16	-2.02	0.84	0.74

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Table 3. Iwao's patchiness regression and Taylor's power law of greenhouse whitefly for summer and autumn crop of tomato

Cropping season	Iwao's patchiness regression			Taylor's power law		
	α	β	R^2	A	B	R^2
Summer crop	-0.1256	1.1808	0.9728	1.0965	1.2020	0.9584
Autumn crop	-0.2592	0.9373	0.8707	0.6607	0.9148	0.7796

both the cropping seasons. The population in summer crop followed negative binomial distribution, whereas the distribution in autumn crop was binomial. It was further observed that at lower population levels in the vegetative growth stage in both the cropping seasons, greenhouse whitefly was distributed randomly whereas in post-flowering stage (reproductive stage), *T. vaporariorum* distribution was aggregated/ clumped in summer crop and regular/ uniform in autumn crop.

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Effect of Plant Extracts on Qualitative Parameters of Guava

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Abstract: The study was carried out to test the potency of some plant extracts for extension of shelf life of guava. Aqueous extract used were obtained from leaves of neem (*Azadirachta indica* A. Juss) and chinaberry (*Melia azedarach*). Guava fruit was dipped in 10% and 20% leaves extract of *A. indica* and *M. azedarach* and were packaged in newspaper and gunny bag and was tested for the storage quality of the fruit at room temperature. The statistical results of the study indicated that coating of leaves extracts and storage period significantly ($P \leq 0.05$) affected all traits. Interaction of aqueous extracts and storage for all traits was also significant. TSS, ascorbic acid and pectin increased with storage and then decreased. Spoilage increased with storage period and at the end, it was highest in control and lowest in fruits dipped in neem 20% and wrapped in newspaper. These results thus showed that surface coating of guava with 20% *A. indica* leaf extract and wrapped in newspaper provided better retention of storage life of fruit.

Keywords: Guava, Fruit Quality, Plant Extracts, Post Harvest, Storage

Guava (*Psidium guajava* L.) is grown successfully throughout tropical and sub-tropical regions of India. Guava fruit is highly perishable and has to be marketed immediately after harvest. A number of post harvest treatments like waxing, fungicidal dip, polyethylene film, etc. have been used to extend the shelf life of fruits (Bhardwaj *et al.,* 2010). However, the use of these substances have their own limitations, as some of them are believed to be ecologically unsafe and economically unviable, besides leaving their residue on the fruit surface, which may have the direct effect on human health. Gainge *et al.* (1984) have documented a number of plants belonging to various families having growth regulating and fungicidal properties, therefore extracts of neem (*Azadirachta indica L.*) and chinaberry (*Melia azedarach* L.) were studied for use as a plant protection agents. They have antifungal and antimicrobial properties. Keeping these in view, the present investigation was undertaken to assess the storability of guava fruits to manage appropriate regulated market supply through judicious use of post-harvest treatments of plant extracts.

MATERIAL AND METHODS

Preparation of treatment solutions: Treatment solutions were prepared from extracts of *A. indica* and *M. azedarach* leaves at different concentrations on the percentage weight basis as per the method described by Gakhukar (1996). The flower and leaves were dried in shade followed by grinding them to a powder form in an electric blender. The extract was prepared by adding 100 ml of distilled water to 100 g of leaf or flower powder and kept overnight. This gave 100% concentration of the plant extract (1:1 w/v). Aqueous solutions of different treatments were prepared using distilled water by diluting the extracts to 10 and 20% and passed through two layers of muslin cloth.

Collection of fruits and the treatment: Medium sized guava fruits of cv. 'Allahabad Safeda', free from any damage and with uniform maturity were harvested when colour changed from dark green to light green from orchard of Sher-e-Kashmir University of Agricultural Science and Technology, Jammu. Fruits were then analysed for different physico-chemical characters at harvest and they were dipped for 10 minutes in various plant extracts as per treatment details: (1) neem leaf extract, 10% wrapped in newspaper (NLE, 10% NP); (2) neem leaf extract, 10% wrapped in gunny bag (NLE, 10% GB); (3) Neem leaf extract, 20% wrapped in newspaper (NLE, 20% NP); (4) neem leaf extract, 20% wrapped in gunny bag (NLE, 20% GB); (5) China berry leaf extract, 10% wrapped in newspaper (CLE 10%, NP); (6) chinaberry leaf extract, 10% wrapped in gunny bag (CLE 10%, GB); (7) chinaberry leaf extract, 20% wrapped in newspaper (CLE 20%, NP); (8) chinaberry leaf extract, 20% wrapped in gunny bag (CLE 20%, GB); (9) control. The fruits were surface dried and kept at room temperature to accesses changes in physico-chemical properties on 4th, 8th, 12th and 16th day. Each treatment was replicated thrice having twenty five fruits in each replication.

Quality components like total soluble solids, pectin and texture were estimated by standard methods. Total

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soluble solids (%) were recorded with Abbes refractometer. Ascorbic acid content (mg/100g) was determined by the procedure using 2, 6-dicholorophenol indophenols dye and pectin was determined by Gravimetric method (Sadasivam, 1996). Fruits were examined visually for per cent spoilage.

RESULTS AND DISCUSSION

TSS of guava on 4th day of storage was maximum (11.37°B) in fruits treated with chinaberry 20% and wrapped in newspaper followed by fruits treated with neem leaf extract, 20% wrapped in newspaper (10.80°B) and minimum (9.80°B) in control. The TSS increased to 12.80°B and 12.50°B in fruits treated with chinaberry and neem leaf extract, 20% and wrapped in newspaper, respectively on 16th day. While in control, TSS on 16th day was 11.20°B. Total soluble solid increased in the increased in the beginning of the storage and then decreased gradually and the decrease was upto 16th day of storage. The results were in accordance with those reported by Chauhan *et al.* (2008) who concluded that neem and chinaberry leaf extracts were capable to retain maximum total soluble solid than control, which might be due to higher respiratory losses in these fruits as there was no barrier to restrict the movement of gases into and out of the fruit.

On 4th day of storage the highest ascorbic acid content of 187.04 mg/100 g pulp was recorded in fruits treated with neem 20% and wrapped in newspaper and in control. The values decreased to 153.09 mg/100 g pulp in fruits treated with neem 20% and wrapped in newspaper and 125.53 mg/100 g pulp in control on 12th day of storage (Table 1). Results reveal that ascorbic acid increased upto 4th day and then decreased gradually during storage. The fall in ascorbic acid content might be due to its oxidation and enzymatic degradation during ripening (Suresh *et al.*, 2008). The decrease might be associated with differential ascorbic acid oxidase activity in fruits as well as its utilization by developing fungi on fruit surface (Singh, 2005). These results are in accordance with the results reported by (Bhardwaj *et al.*, 2010) that neem reduces respiration rate as well as oxidation in the orange. Similar results had been reported by Bhardwaj and Sen (2003) in mandarin orange.

Pectin content decreased significantly after 4th day of storage. The highest pectin content on 4th day was 2.70 per cent in fruits treated with neem 20% and wrapped in newspaper followed by fruits treated with china berry 20% and wrapped in newspaper and lowest pectin content was in control. On 12th day the pectin content decreased to 0.98 per cent in fruits treated with neem 20% and wrapped in newspaper and 0.49 per cent in control. On 16th day of storage further decline was observed. Azadirachtin is reported to retard the deestrification of pectin, thereby slowing down its breakdown resulting in higher pectin content in such fruits (Gakhukar, 1996). These findings are also in line with those reported by Chauhan *et al.* (2008) and Wijewardane and Guleria (2009) in apple that neem extract is the most effective in retaining highest pectin content.

On 8th day maximum (22.22 per cent) spoilage was observed in control. On 12th day, the spoilage percentage increased to 38.89 per cent in control (Table 2). The interaction between treatment and storage was found to be significant. No spoilage was observed on 4th day. However, spoilage per cent showed a steady increase from 8th day to 16th day of storage. Among treatments, neem 20% and news paper wrapping decreased the spoilage significantly followed

Table 1. Effect of plant extracts on total soluble solids, ascorbic acid (mg/100g) and pectin (%) of guava fruits.

Treatments	4th day	8th day	12th day	16th day	Mean	4th day	8th day	12th day	16th day	Mean
	Total Soluble Solids (TSS)					Ascorbic acid (mg/100g)				
NLE 10%, NP	10.50	11.27	11.53	12.03	11.33	173.78	157.04	145.44	132.50	152.19
NLE 10%, GB	10.40	11.10	11.47	11.93	11.23	171.54	153.84	144.86	131.49	150.43
NLE 20%, NP	10.80	11.77	11.83	12.50	11.73	187.04	158.90	153.09	143.76	160.70
NLE 20%, GB	10.60	11.50	11.63	12.10	11.46	184.07	156.64	149.48	138.93	157.28
CLE 10%, NP	10.70	11.63	11.77	12.33	11.61	181.42	155.93	147.39	136.46	155.30
CLE 10%, GB	10.53	11.30	11.40	12.17	11.35	186.73	152.21	145.64	133.77	154.59
CLE 20%, NP	11.37	12.10	12.23	12.80	12.13	181.85	159.16	151.87	141.63	158.63
CLE 20%, GB	10.67	11.50	12.00	12.73	11.73	179.13	154.96	147.64	135.28	154.25
Control	9.80	10.70	10.87	11.20	10.64	143.87	130.72	125.53	120.63	130.19
Mean	10.60	11.43	11.64	12.20		176.60	153.27	145.66	134.94	
	Factors		C.D. (p=0.05)			Factors			C.D. (p=0.05)	
	Treatment (A)		0.22			Treatment (A)			0.47	
	Storage (B)		NS			Storage (B)			0.31	
	Interaction (A X B)		0.43			Interaction (A X B)			0.94	

NLE: Neem Leaf Extract; CLE: Chinaberry Leaf Extract; NP: Newspaper; GB: Gunny Bag

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Table 2. Effect of spoilage (%) and texture of guava fruits

Treatments	8th day	12th day	16th day	Mean	4th day	8th day	12th day	16th day	Mean
	Spoilage % age				Texture				
NLE 10%, NP	0 (0.71)	22.22 (4.77)	33.33 (5.82)	18.52	8.55	8.91	6.34	5.81	7.40
NLE 10%, GB	0 (0.71)	27.78 (5.32)	44.44 (6.70)	24.07	8.42	8.76	6.15	5.59	7.23
NLE 20%, NP	0 (0.71)	11.11 (3.41)	22.22 (4.77)	11.11	8.84	9.03	7.98	6.57	8.11
NLE 20%, GB	0 (0.71)	16.67 (4.14)	38.89 (6.28)	18.52	8.67	8.97	6.45	5.56	7.41
CLE 10%, NP	0 (0.71)	16.67 (4.14)	33.33 (5.82)	16.67	8.46	8.78	6.22	5.73	7.30
CLE 10%, GB	0 (0.71)	22.22 (4.77)	44.44 (6.70)	22.22	8.49	8.89	6.29	6.73	7.60
CLE 20%, NP	0 (0.71)	16.67 (4.14)	27.78 (5.32)	14.82	8.77	8.94	7.39	6.66	7.94
CLE 20%, GB	0 (0.71)	22.22 (4.77)	44.44 (6.70)	22.22	8.66	8.86	6.29	5.26	7.27
Control	22.22 (4.77)	38.89 (6.28)	66.67 (8.20)	42.59	8.34	7.80	5.10	4.47	6.43
Mean	2.47	21.61	39.50		8.58	8.77	6.47	5.82	
	Factors	C.D. (p=0.05)			Factors	C.D. (p=0.05)			
	Treatment (A)	0.11			Treatment (A)	0.15			
	Storage (B)	0.11			Storage (B)	0.10			
	Interaction (A X B)	0.12			Interaction (A X B)	0.31			

*Figures given in parentheses are transformed (square root) values

NLE: Neem Leaf Extract; CLE: Chinaberry Leaf Extract; NP: Newspaper; GB: Gunny Bag

by treatment with chinaberry 20% and wrapping in newspaper. Reduction in spoilage due to rotting with the neem extract may be attributed to the presence of the principle compound azadirachtin, which has the ability to check the growth of microbes that are responsible for causing spoilage. The results are also in conformity with the findings of Chauhan *et al.* (2008) and Okigbo *et al.* (2010). Gakhukar (1996) suggested that botanical extracts have the capability to act as anti-feedent and anti-repellent and thereby inhibiting the pathogenicity of various organisms.

Texture scores of guava fruit of different treatments revealed that on 4th day, the maximum score of 8.84 was recorded in fruit treated with neem 20% and wrapped in newspaper and the minimum score of 8.34 in control. On 12th day of storage, the scores decreased to 7.98 and 5.10, respectively. Texture score of guava decreased with increase in storage period. The better score observed for texture at the optimum stage could be due to conversion of protopectin into pectin and then pectin into pectinic acid, which disintegrated the cell structure, and caused lowering of sensory score (Suresh *et al.*, 2008). The results are in conformity with that of Chauhan (2008) who reported that 20% neem was most effective.

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Indian Journal of Ecology

Effects of Metal Contaminated Soils on the Survival, Growth and Duration of Life Span of Juveniles of Earthworm, *Eisenia fetida* (Savigny)

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Abstract: Juveniles of *Eisenia fetida* were exposed for 11 weeks to soils contaminated with cadmium, lead and nickel collected from four different sites in the vicinity of Buddah Nullah, Ludhiana and uncontaminated soil sample was taken as control. Survival, growth and time taken to reach sexual maturity in juveniles reared in contaminated soils were compared with juveniles in uncontaminated soil. The effects of metal contaminated soils could be attributed both to the direct toxicity of the metals and to changes in scope for growth of the exposed worms. Worms were found sensitive to elevated metal concentrations in first few weeks of the experiment as some mortality occurred in worms during that time of the experiment. Growth was also found affected in worms reared in contaminated soil samples. Duration to attain sexual maturity was found maximum in soil sample taken from the site having highest concentration of lead and nickel among the different samples. Results of the study indicated that elevated metal concentrations in soil adds to the sensitivity of the worms since the different parameters like survival, growth and duration to reach sexual maturity were seen highly affected in the juveniles of *E. fetida* in the contaminated soils.

Key Words: Heavy Metals, *Eisenia fetida*, Juveniles, Sexual Maturation, Toxicity

Earthworms are important component of soil system, mainly because of their favorable effects on soil structure and function. In addition, earthworms help to increase soil fertility by formation of an organic matter layer in top soil. Metal pollution may disturb soil ecosystem by affecting the structure of soil invertebrate communities. Heavy metals have been shown to reduce growth, slow sexual development, reduce juvenile viability and cause mortality. The juveniles of *Eisenia fetida* (Savigny) have been found to be more sensitive to pollutants than adults. Acute and chronic earthworm toxicity tests were successfully applied to assess the toxicity of contaminated soils in urban, mining and smelting and industrial areas. Earthworms, especially the compost worm *E. fetida* are model organisms for assessing the effects of various chemicals on terrestrial invertebrates. *E. fetida* (Savigny) are known to be absent or severely reduced in numbers in soils in the vicinity of lead, cadmium and zinc smelting works. Moreover in a polluted environment, changes to individual energy budgets will occur, as the organism expends energy resisting the contaminant by avoidance, exclusion, removal or complexing (Sibly and Calow, 1989; Donker, 1992). This additional energy requirement will decrease the scope for growth of the exposed animals and will reduce growth, differentiation, cocoon production and ultimately a number of important life history characteristics such as time to sexual maturity and generation time. Buddah Nullah has become a major source of pollution in the region as it get polluted after entering the highly populated and industrialized Ludhiana city, turning it into an open drain. Heavy metals in the Buddah Nullah stream leeches into the nearby soil and affects the population of many soil invertebrate communities and earthworms are one of the first receptors to be affected by soil contamination (Zaltauskait and Sodiene, 2010). The objective of present study was to examine the survival, growth and sexual maturation time of juveniles of *E. fetida* in heavy metal contaminated soils collected from different sites around Buddah Nullah stream, Ludhiana since no work has been reported earlier in this area around Buddah nullah using earthworm as a bio-indicator for heavy metal toxicity.

MATERIAL AND METHODS

The present work was carried out in campus of Punjab Agricultural University, Ludhiana. Metal contaminated soils were collected on the same day from four different sites in the vicinity of Buddah Nullah, Ludhiana. The different sites included Chand Cinema, Sunder Nagar, Tajpur Road and Shivpuri Area around Buddah Nullah (Fig.1). All the soil samples were collected at least 2 meters away from the main stream. About 5 kg of soil was collected from top 2 cm layer at each site after removal of surface vegetation and litter in transparent polythene bags. Colored bags were not used to avoid any extra contamination of soil sample. All the bags were marked with respect to the sites from which the samples were collected. A control sample of soil was collected from an uncontaminated field in PAU campus.

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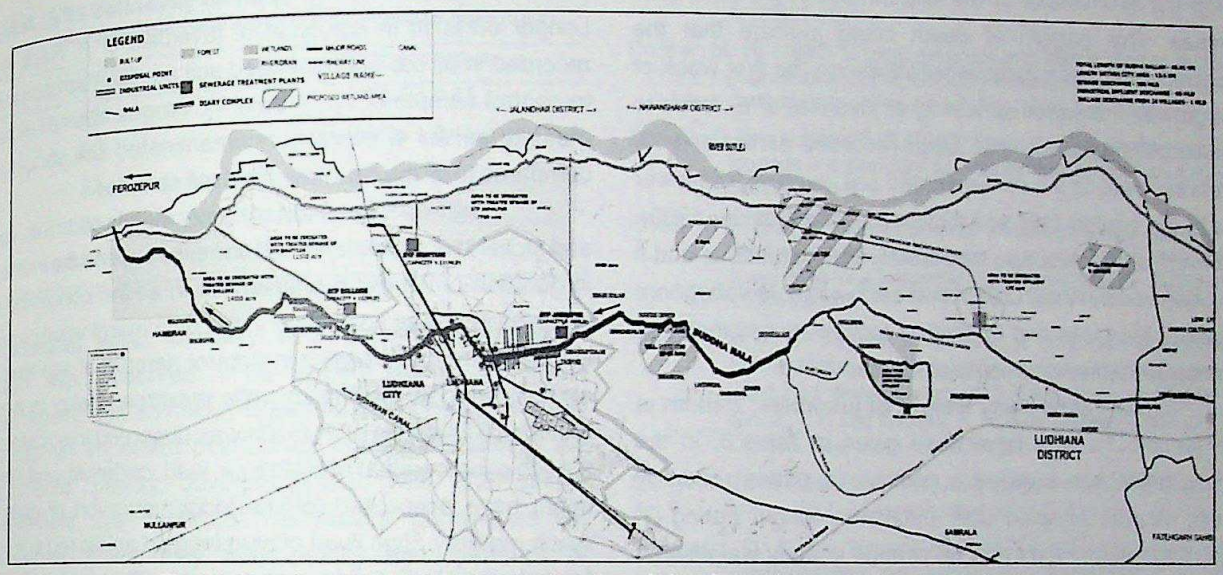

Fig. 1. Map of Buddah Nullah showing location of sites from where samples were collected

Soil aggregates were crushed while still damp and placed in a fan oven at 60°C for 2 days to dry. A subsample of soil was collected for the determination of cadmium, lead and nickel concentrations in the soils by flame atomic absorption spectrophotometry. Results of analysis of soils are depicted in Table 1. All the soil samples were passed through a 2mm mesh and 100 g of soil was placed in each Petri plate of size 14.8cm × 14.8cm. Distilled water was added to give a moisture content of 65% of field capacity and soil was left to stabilize for 72 hours prior to addition of worms.

To study the effect of metal contaminated soil on growth, about one week old hatchlings of *E. fetida* were taken from the mass culture kept at the laboratory of the department. The selected worms were acclimatized for seven days. The juveniles were weighed and inoculated into prepared soil petriplates and after 3 hours they were checked to ensure that all the worms had burrowed into the soil. All the petriplates were covered to prevent water loss. To ensure the growth, the worms were supplied with 5 g dried cattle manure per week.

At weekly intervals worms were sorted from all the soil samples and monitored for different parameters like survival, weight change and sexual maturity. Sexual development of worms was assessed according to scheme described by van Gestel *et al* (1991) to identify different stages of growth of worms. Worms with full clitellum were recorded as adult, those with a full tubercle pubertatis but no clitellum as sub-adults and individuals with neither of these structures as juveniles. The data was statistically analyzed by Analysis of Variance (ANOVA) using computer software CPCS1.

RESULTS AND DISCUSSION

Metal composition of soil: Concentrations of different heavy metals *i.e* cadmium, lead and nickel have been depicted in table 1. All the contaminated samples contained elevated levels of heavy metals. Among all the contaminated soil samples, maximum concentration of cadmium (0.29 ppm), lead (4.18 ppm) and nickel (2.29 ppm) was found in sample 4 and 2. While metal levels at PAU campus was within the range typical for an uncontaminated

Table 1. Concentrations of different heavy metals in soil samples

Soil sample*	Concentration of heavy metals (ppm)		
	Cadmium (Cd)	Lead (Pb)	Nickel (Ni)
S1	0.23	3.86	1.87
S2	0.18	4.18	2.29
S3	0.25	3.35	1.43
S4	0.29	3.96	2.14
Control	0.20	1.75	0.50

*S1, S2, S3 and S4 are the soil samples taken from Chand Cinema, Sunder Nagar, Tajpur Road and Shivpuri area, respectively

Survival of juveniles of *E. fetida*: Hatchlings of *E. fetida* when reared in control soil sample taken from PAU campus did not show any mortality and survived well up to 11 weeks. Maximum mortality was recorded in sample 3 and all the animals died in this soil sample after one week of rearing as shown in table 2. High mortality percentage of juveniles shows the sensitivity of juveniles to elevated levels of heavy metals. 50% survival was recorded in case of sample 2 while worms in sample 4 survived till end of the experiment. No significant mortality of *E. fetida* was observed in the soils collected from the campus and most of the worms died

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during the first weeks of the experiment in contaminated samples. This pattern of death could indicate that the juveniles were particularly sensitive during the first week of their growth. Increased sensitivity of juveniles of *E. fetida* to metallic pollutants has also been recorded earlier and for worms exposed to the contaminated soil, survival was lower than in the control field soil (Spurgeon and Hopkin, 1999). Earthworms try to escape moderately toxic situations and it was observed by Khalil (2013) that earthworm *Allolobophora caliginosa* feed less and *Pheretima hawayana* escaped into their burrows when exposed to arsenate.

Changes in body weight of juveniles: Pattern of body weight changes have been given in Table 3. In the control, hatchlings showed a continuous pattern of body growth. Worms attained their maximum weight during 9th week of the experiment and no change in body weight was observed after that till end of the experiment.

The worms reared in all the metal-contaminated soils reach the lower weight or need more time to reach the maximum weight than in non-polluted control soil. A number of studies on soil invertebrates have recorded a reduction in growth in animals exposed to metal contaminated sites. Growth of earthworm *Octodrilus complanatus* was found affected by aluminum level, which caused reduction in earthworm protein content (Bilialis *et al.*, 2013). However such effects can frequently be attributed to a reduction in consumption due to avoidance of the contaminated food (Drobne and Hopkin, 1995).

Duration of life span of juveniles of *E. fetida*: Longer duration in life cycle of juveniles of *E. fetida* was recorded in all the contaminated soil samples as compared to control sample of soil (Table 4). Worms attained sexual maturity earlier in control uncontaminated soil sample as compared to all the contaminated soil samples.

High concentration of heavy metals cadmium, lead and nickel in contaminated soil samples caused the increase in duration of life cycle of juveniles in all the contaminated samples of soil as compared to the uncontaminated control. Juveniles matured earlier in control sample of soil than in contaminated soil samples while maximum delay to reach maturity in juveniles of *E. fetida* was observed in soil sample 2. High concentration of metals *i.e.* lead, cadmium and nickel might have accounted for the longer duration of days to reach maturity. High level of aluminum in acidic red soil was found harmul to *E. fetida* as observed by Zhang *et al.* (2013). Selection of life history parameters can also occur when populations are exposed to different factors (such as pollutants) that reduce survival and lower reproductive effort. If there is an increased energy demand for metal sequestration and elimination, this will decrease the energy available for sexual maturation and will ultimately slow down the maturation in animals exposed to the contaminated soils (Spurgeon and Hopkin, 1996).

The results of the present study indicated that survival, growth and sexual maturation time of juveniles of *E. fetida* was found affective when juveniles reared in metal

Table 2. Per cent survival of hatchlings of *E. fetida* in uncontaminated and metal contaminated soil samples

Soil sample*	Number of weeks										
	1	2	3	4	5	6	7	8	9	10	11
S1	100	100	100	100	100	100	100	100	100	100	100
S2	100	75	75	75	75	75	50	50	50	50	50
S3	100	-	-	-	-	-	-	-	-	-	-
S4	100	100	100	100	100	100	100	100	100	100	100
Control	100	100	100	100	100	100	100	100	100	100	100

Table 3. Weekly changes in body weights (g) of hatchlings of *E. fetida* in uncontaminated and metal contaminated soil samples

Soil sample**	Number of weeks										
	1	2	3	4	5	6	7	8	9	10	11
S1	0.048 ± 0.01	0.050 ± 0.01	0.073 ± 0.02	0.085 ± 0.02	0.098 ± 0.03	0.12 ± 0.03	0.14 ± 0.03	0.14 ± 0.04	0.15 ± 0.04*	0.16 ± 0.05*	0.19 ± 0.06*
S2	0.036 ± 0.00	0.052 ± 0.01	0.044 ± 0.014	0.064 ± 0.02	0.080 ± 0.027	0.064 ± 0.03	0.13 ± 0.02	0.22 ± 0.03	0.33 ± 0.02*	0.33 ± 0*	0.46 ± 0*
S3	0.036 ± 0.00	-	-	-	-	-	-	-	-	-	-
S4	0.033 ± 0.00	0.058 ± 0.01	0.083 ± 0.02	0.12 ± 0.03	0.15 ± 0.04	0.21 ± 0.05	0.25 ± 0.05	0.23 ± 0.05	0.23 ± 0.05*	0.32 ± 0.07*	0.41 ± 0.07*
Control	0.050 ± 0.014	0.051 ± 0.01	0.061 ± 0.01	0.064 ± 0.01	0.088 ± 0.01	0.15 ± 0.02	0.19 ± 0.02	0.35 ± 0.03	0.49 ± 0.007	0.49 ± 0.007	0.49 ± 0.007

Values are mean ± S.E of four replicates
* Values are significant at 5% level of significance

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Table 4. Duration of life span of juveniles of *E. fetida* in uncontaminated and metal contaminated soil samples

Soil Sample	Number of days
S1	45.25 ± 0.41
S2	53.25 ± 0.41
S3	-
S4	43.75 ± 0.41
Control	28.50 ± 0.55

contaminated soils. Mortality and discontinuous growth pattern was observed in juveniles reared in metal contaminated soil samples. Delay to gain sexual maturity was also an important point to be considered during the experimental period. Juvenile growth rate and sexual development are important life history parameters for earthworms, since they may modify the dynamics of earthworm populations in the field. The findings of this paper can be helpful in assessing the impact of toxicity of different heavy metals towards population of earthworms in naturally contaminated soils.

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Influence of Edaphic Factors on Population Density of Slug, *Filicaulis alte* Ferussac in Vegetable Crops of Punjab

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Abstract: Studies conducted in vegetable fields of three villages viz; Bhadalwad, Sanghera and Dasaunda Singh Wala, Punjab revealed that slug density varied with weather conditions and soil components like organic matter, nitrogen, phosphorus, potassium, etc. In all the respective villages, slug density was found to be high during month of August and September. Slug density was noted by placing damp sacs in all the three villages. Slug density in Dasaunda Singh Wala village of district Sangrur was found to be significantly ($p>0.05$) more than other two villages that are Bhadalwad and Sanghera village of district Barnala. Bulk density found to be significantly less and potassium, phosphorus, soil electrical conductivity, organic matter and total porosity were found to significantly more in Dasaunda Singh Wala village. As maximum slug density was found in Dasaunda Singh Wala village therefore, slugs preferred low bulk density and high porosity and other soil components.

Key Words: Brown Slug, Damage, Slug Density, Vegetable Crops, Edaphic Factors

Slugs are important molluscan pests of a wide range of ornamental and vegetable plants in permanently moist regions or in rainy months. Slugs move by gliding on a muscular foot. The muscles constantly secrete mucus which later dries to form the silvery "slime trail" that signals the presence of either pest.

Brown slug with black spots (*Filicaulis alte* Ferrusac) was found to inhabit vegetable crop fields in Kaddon village of Ludhiana District, Punjab (Kaur and Mehta, 2013). Slugs injure plants by chewing holes in various sizes in the leaves and stems. These holes may be in the middle of the leaf or on the edge. The early seedlings stages are most susceptible to slugs; slugs can sometimes consume the entire seedling. Once the crop has passed the 6-leaved stage, the damage is generally superficial. The slugs reduce the vigor of some crops by killing seeds, destroying stems or growing points or by reducing leaf area. This may slow down crop development and reduce yield (Jagtap, 2000). Slugs also cause damage to beans, cabbage, cauliflower, tomato, strawberry, grape, banana (Flint, 2007). The older seedlings of vegetable saplings are damaged to an extent in by slug *F. alte*, compared to younger seedlings both by leaf damage and stem cutting (Kaur and Kaur, 2003) sponge gourd leaf margins were of 10.36 per cent and stem cutting was to the extent of 9.99 per cent.

Activity of slug *F. alte* in vegetable fields was affected by interactive effect of various ecological conditions like air and soil temperature, soil texture and structure, pH, soil moisture, soil organic carbon, phosphorus and nitrogen components, availability of shade and shelter and presence of wet and damp conditions (Kaur and Kaur, 2004; Kaur and Kaur, 2006). The slug *F. alte* in vegetable fields and gastropods in plant nurseries preferred sandy loam alkaline soil, medium in organic matter and nitrogen, high in phosphorus and potassium in soil. Higher is the organic matter, phosphorus and potassium in soil, higher is the slug density and hence greater damage (Kaur and Chhabra, 2009). However, soil moisture, soil temperature, sunshine, soil bulk density and porosity were the more effective factors to determine surface active gastropod population (Panjgotra, 2012). Slug density was maximum during third week of August, i.e. 3.33± 0.66 slugs per m^2 (with casein) and 3.00± 1.00 slugs per m^2 (without casein) during first week of September (Mehta, 2010).

MATERIAL AND METHODS

Vegetable fields at three villages viz; Bhadalwad, Sanghera both of district Barnala and Dasaunda Singh Wala of district Sangrur were surveyed. Population density, structure and fluctuation throughout the crop period of various vegetables were studied by counting the number of slugs active at surface by placing damp sacs at 10 sites selected randomly in each village at fortnightly intervals. Sacs were moistened by sprinkling water on them and placed in evening (1800-1900 hr) and slugs under them were collected in the morning (0600-0700 hr) on the third day in all the villages. Length, breadth and weight of caught specimen were measured in the laboratory. Soil moisture and soil

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temperature were also observed along with slug collection. Soil temperature was noted with the help of thermometer.

Soil samples were taken from the experimental sites at depth of 0-15 cm for testing of soil pH, soil texture, and organic matter, inorganic components like nitrogen, phosphorus and potassium at the Department of Soils, PAU, Ludhiana. Bulk density of soil was determined in the experimental sites with the help of cylindrical steel ring. The ratio of dry mass of the soil inside the soil core to the inner volume of the steel ring was expressed as bulk density in g/cm³. Porosity and particle density were also calculated. The analysis of all the edaphic factors was carried out with density data of slugs from vegetable fields of three villages.

RESULTS AND DISCUSSION

Slug density population and its structure at Bhadalwad village in relation to edaphic factors: The slugs were available from March to mid November, for remaining period they were in hibernation. In March, slug density was found to be 0.4 slug/m² with soil temperature of 21.36°C (at 5cm) and 20.87°C (at 10 cm) and soil moisture of 15.6 per cent. This slug density was further increased on first week of May. Slug population further decreased in June i.e. 0.4 slug/m² with soil moisture content of 13.50 per cent and with maximum soil temperature of 34.50°C at 5cm and 33.50°C at 10cm. Maximum slug density population density was found in last week of August (31 August) in Bhadalwad village i.e. Maximum soil moisture was found on 31 August, so that the slug population. This population further decreased to 0.3 at soil moisture of 22.60 per cent and soil temperature of 19.02°C (at 5cm) and 17.90°C (at 10cm). The maximum adult size of the slug, *F. alte* ranged between 6.1 cm in length, 1.4cm in breadth and the average weight was 6.1 g (Table 5) in Bhadalwad village (Table 1 and 5).

Slug density population and its structure at Sanghera village in relation to edaphic factors: The slugs were available from March to mid November, for remaining period they were in hibernation. Least slug population was found in March i.e. 0.1 slug/m² with soil moisture content of 15 per cent and soil temperature of 20.77°C (at 5cm) and 20.27°C (at 10 cm). This slug density was further increased in May. The slug population decreased to 0.2 on 7 June with soil moisture content of 8.40 per cent and with soil temperature of 33.60°C at 5cm and 31.01°C at 10cm. This decrease in slug density might be due to maximum soil temperature. Maximum slug population density was found in first week of September in Sanghera village i.e. 1.3±0.26, where soil moisture found was maximum 25.40 per cent and soil temperature found was 23.80°C at 5 cm and 23.65°C at 10 cm. This slug population further decreased in first week of November The maximum adult size of the slug, *F. alte* ranged between 5.8 cm in length, 1.4cm in breadth and the average weight was 6.4 g (Table 2 and 5).

Table 1. Population density of brown slug, *Filicaulis alte* in vegetable field at Bhadalwad village in relation to edaphic factors (Mean ±SE)

Date/Year 2013	Number of slugs active at surface m^{-2}	Per cent soil moisture	Mean soil temperature* (°C) at different depth	
			5 cm	10 cm
17-Mar	0.4±0.16	15.6±0.65	21.36±0.18	20.87±0.27
01-Apr	0.3±0.15	20.00±0.84	22.62±0.05	22.40±0.05
17-Apr	0.4±0.16	21.60±1.22	23.75±0.02	23.20±0.00
03-May	1.0±0.21	21.00±1.16	27.27±0.42	26.77±0.57
19-May	0.5±0.22	22.20±0.96	30.95±0.34	30.45±0.15
05-Jun	0.4±0.22	13.50±1.72	34.50±0.05	33.50±0.31
21-Jun	0.6±0.22	13.60±1.02	30.06±0.02	29.98±0.06
07-Jul	0.4±0.16	16.20±0.81	29.92±0.16	30.07±0.40
23-Jul	1.1±0.31	19.20±0.67	28.43±0.22	28.25±0.08
08-Aug	1.0±0.25	17.80±1.13	26.41±0.16	26.28±0.03
24-Aug	0.8±0.24	19.40±0.66	25.98±0.23	25.63±0.26
31-Aug	1.2±0.24	26.40±0.58	23.77±0.02	23.46±0.01
16-Sep	0.4±0.27	25.00±0.68	22.82±0.02	22.76±0.07
02-Oct	0.8±0.29	22.60±0.52	22.92±0.01	22.70±0.00
18-Oct	0.6±0.16	22.80±0.32	22.87±0.07	22.56±0.11
3-Nov	0.3±0.15	22.60±0.42	19.02±0.47	17.90±0.59

* Mean of morning and evening soil temperature

Slug density population and its structure at Dasaunda Singh Wala village in relation to edaphic factors: The slugs population was available from March to November and being in hibernation for remaining period of year. 0.4 slug/m² were found on 22 March at soil moisture content of 18.20 per cent and soil temperature of 21°C (at 5cm) and 20.70°C (at 10 cm). This slug population was further increased to 1.3 on 9 May at soil moisture content of 24.40 per cent and soil temperature of 26.35°C (at 5 cm) and 25.55 (at 10 cm). This slug population further decreased in June to. After this period slug population density was stable from July to August. Maximum slug population density was found on 21 September 1.5 slug/m² where soil moisture found was maximum i.e. 25.60±0.65 per cent and soil temperature found was 22.92°C at 5 cm and 22.81°C at 10 cm. This slug population further decreased 8 November. The maximum adult size of the slug, *F. alte* ranged between 6.2 cm in length, 1.4 cm in breadth and the average weight was 6.5 g (Table 3 and 5).

The results indicated that the seasonal factors (soil moisture and soil temperature) might be optimum for the activity of slugs. Trends of slug activity in present findings were similar to as reported earlier by Kaur et al. (2012). They reported that slugs were active from March to November and

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Table 2. Population density of brown slug, *Filicaulis alte* in vegetable field at Sanghera village in relation to edaphic factors (Mean ±SE)

Date/Year 2013	Number of slugs active at surface m^{-2}	Per cent soil moisture	Mean soil temperature* (°C) at different depth	
			5 cm	10 cm
19-Mar	0.1±0.15	15.00±0.90	20.77±0.27	20.27±0.47
04-Apr	0.4±0.16	18.70±1.27	22.28±0.22	21.54±0.24
20-Apr	0.4±0.22	20.60±0.66	23.08±0.29	22.67±0.17
06-May	1.1±0.10	24.00±0.73	26.99±0.38	26.30±0.45
22-May	0.5±0.22	20.60±0.79	30.35±0.20	29.77±0.17
07-Jun	0.2±0.15	8.40±0.40	31.60±0.21	31.01±0.18
23-Jun	0.4±0.22	14.00±0.51	31.17±0.28	30.06±0.46
09-Jul	0.8±0.20	15.40±0.73	28.68±0.09	28.19±0.27
25-Jul	0.5±0.16	17.40±0.66	28.65±0.03	28.96±0.15
10-Aug	0.7±0.21	18.20±0.35	27.62±0.17	27.12±0.27
26-Aug	1.0±0.25	21.20±1.04	25.29±0.06	24.98±0.05
02-Sep	1.3±0.26	25.40±0.78	23.80±0.26	23.65±0.37
18-Sep	0.9±0.23	23.60±0.40	23.24±0.01	23.13±0.04
04-Oct	1.0±0.29	22.60±0.30	22.94±0.02	23.20±0.46
20-Oct	0.5±0.29	22.20±0.20	22.75±0.15	22.41±0.14
05-Nov	0.4±0.16	22.20±0.35	22.37±0.19	21.89±0.34

* Mean of morning and evening soil temperature

Table 3. Population density of brown slug, *Filicaulis alte* in vegetable fields at Dasaunda Singh Wala village in relation to edaphic factors (Mean ±SE)

Date/Year 2013	Number of slugs active at surface m^{-2}	Per cent soil moisture	Mean soil temperature* (°C) at different depth	
			5 cm	10 cm
22-Mar	0.4±0.16	18.20±0.35	21.00±0.30	20.70±0.20
07-Apr	0.4±0.16	20.50±0.47	23.17±0.26	22.64±0.28
23-Apr	0.6± 0.22	22.60±0.42	24.14±0.32	23.51±0.52
09-May	1.3±0.26	24.40±0.40	26.35±0.13	25.55±0.20
25-May	0.6±0.22	22.20±0.46	30.00±0.17	29.35±0.30
10-Jun	0.5±0.16	12.20±0.96	30.56±0.38	29.90±0.55
26-Jun	0.6±0.22	14.40±1.06	27.14±0.13	26.91±0.01
12-Jul	1.0±0.20	18.40±0.40	27.52±0.45	27.43±0.27
28-Jul	1.0±0.10	17.80±0.55	27.05±0.24	26.83±0.29
13-Aug	1.0±0.21	17.60±1.02	26.25±0.15	26.02±0.42
29-Aug	1.2±0.23	22.40±1.42	24.52±0.07	24.26±0.05
05-Sep	0.8±0.29	24.80±0.53	23.41±0.00	23.23±0.06
21-Sep	1.5±0.24	25.60±0.65	22.92±0.15	22.81±0.22
07-Oct	1.0±0.21	23.20±0.44	22.40±0.05	22.22±0.10
23-Oct	1.2±0.24	22.60±0.30	22.24±0.16	22.03±0.09
08-Nov	0.8±0.20	22.40±0.40	20.75±0.20	20.27±0.22

* Mean of morning and evening soil temperature

more so from June to September. These remained in hibernation from December to February. Higher numbers of slugs were found during the month of August and September in vegetable field of Kaddon village, Ludhiana. According to Jagtap (2000) a close relationship existed between densities of slugs and water holding capacity of soil. Measures undertaken to increase the water holding capacity of the soil, thus create more favorable conditions for gastropods.

Comparison of slug population density in three villages in relation to soil components: The results of comparison of different soil components in vegetable fields at three villages indicate that the slugs at Bhadalwad village preferred sandy loam soil with medium range of organic matter, high range of nitrogen, phosphorus, potassium and

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alkaline soil. In Sanghera village, slugs preferred sandy loam soil with medium range of organic matter, medium range of nitrogen and high amount of potassium, phosphorus and alkaline soil. At Dasaunda Singh Wala village slugs preferred sandy loam soil with high range of organic matter, medium range of nitrogen and with high range of phosphorus and potassium and alkaline soil. In Dasaunda Singh Wala village significantly more population density was found than other two villages. All the soil components except pH, clay content and particle density were found to be significantly different in Dasaunda Singh Wala village than at Bhadalwad and Sanghera village. Bulk density was found to be significantly less and porosity was found to be significantly more in Dasaunda Singh Wala village than other two villages. Therefore, slug density found was also significantly more in Dasaunda Singh Wala village than other two villages (Table 4).

In findings of present study it was seen that maximum slug density was found in Dasaunda Singh Wala village, where slug density was significantly more than slug density found in other two villages. This might be due to significant difference in soil components in three villages. In Dasaunda Singh Wala village, higher soil EC, organic matter, less nitrogen, more potassium and phosphorus was

Table 4. Analysis of different soil components taken from the vegetable fields of three villages

Soil characteristics	Bhadalwad village	Sanghera village	Dasaunda Singh Wala village	C.V.	CD (5%)
Soil pH	7.93±0.70	7.83±0.41	7.43±0.33	11.35	-
Soil EC	0.41±0.00	0.32±0.01	0.54±0.03	9.98	0.85
Sand (%)	59.10±0.98	48.26±2.54	51.66±0.66	6.31	6.68
Silt (%)	15.20±0.55	9.50±0.68	17.43±0.70	12.38	3.47
Clay (%)	25.43±1.77	27.36±0.29	26.16±2.39	11.34	-
Organic Matter (%)	0.46±0.02	0.51±0.01	0.76±0.02	7.10	0.81
Nitrogen (kg/acre)	230.66±6.40	206.33±8.11	204.33±3.29	5.09	21.73
Phosphorus (kg/ acre)	36.03±2.18	31.40±1.41	44.70±1.67	12.81	9.56
Potassium (kg/ acre)	151±2.08	149.66±3.94	180.00±5.79	4.55	14.56
Bulk density (g/cm^3)	1.44±0.01	1.44±0.01	1.36±0.00	1.84	0.52
Particle density (g/cm^3)	2.26±0.09	2.12±0.06	2.49±0.16	10.57	-
Porosity (%)	47.33±1.09	45.93 ±0.64	53.80±1.48	4.61	4.51
Overall Slug density	0.64±.07	0.63±0.06	0.94±0.08	44.50	0.23

Values are Mean ± SE; * Significant at p > 0.05

Table 5. Seasonal variation in number and size of slugs active on surface in vegetable fields at three villages

Period of the year (2013)	Number of slug caught	Length (cm)	Breadth (cm)	Weight (g)
		Bhadalwad village (Distt. Barnala)		
March-April	11	2.4-3.2	0.4-0.6	2.8-3.6
May	15	3.0-4.0	0.5-0.7	3.4-4.5
June-July	25	2.1-5.6	0.5-1.4	2.5-5.5
August-September	39	3.6-5.5	0.7-1.2	4.2-6.0
October-November	17	4.2-6.1	0.7-1.2	3.9-6.1
		Sanghera village (Distt. Barnala)		
March-April	5	2.5-3.6	0.4-0.6	2.9-4.1
May	16	3.2-4.5	0.5-1.1	3.5-4.8
June-July	19	2.8-5.6	0.7-1.4	2.2-6.4
August-September	39	3.2-5.6	0.7-1.2	3.6-6.2
October-November	20	4.1-5.8	0.6-1.2	3.8-5.2
		Dasaunda Singh Wala village (Distt. Sangrur)		
March-April	15	2.5-3.0	0.4-0.7	2.5-3.6
May	19	3.1-4.8	0.6-0.8	3.8-5.2
June-July	37	2.6-5.8	0.6-1.3	3.3-6.5
August-September	49	3.1-6.2	0.6-1.4	3.9-6.2
October-November	31	3.2-5.9	0.7-1.2	4.1-6.0

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found than other villages. Less bulk density and high porosity was found in Dasaunda Singh Wala village which was significantly different with other two villages. Therefore, maximum slug density was found in Dasaunda Singh Wala village. Kaur *et al.* (2012) reported that the soil at Kaddon village vegetable fields was more alkaline, with higher EC, nitrogen, phosphorus and total porosity but lower organic matter and bulk density as compared to Doraha village. This indicates that the slugs might prefer alkaline soil with lower bulk density and high porosity. Godan (1983) reported that the number of individuals as well as the variety of species is higher in alkaline soil than on wide variety of soils. Davis (1989) also reported the similar results with present findings that increased soil compaction (bulk density) at levels within the range in arable fields can reduce the slug mobility and thus damage to the crops.

These results, thus pointed out that slug, *F. alte* preferred sandy loam soil in all the three villages. Maximum slug density population was found maximum at Dasaunda Singh Wala village with low bulk density of soil, nitrogen and higher soil EC, organic matter, potassium, phosphorus and porosity than other villages.

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Virulence of *Bacillus thuringiensis* isolates against *Chilo partellus* (Swinhoe)

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Abstract: The spore crystal complex of five *Bacillus thuringiensis* isolates were prepared and evaluated against second and third instar larvae of *Chilo partellus* (Swinhoe) under laboratory conditions. Among these isolates, *Bacillus thuringiensis* 4D4 caused 82.22 per cent mortality against second instar larvae after 10 days of treatment and was at par with MTCC 868 and commercial formulation DELFIN. Similarly, Bacillus isolate MTCC 868 caused 75.55 per cent mortality against third instar larvae and was at par with 4D4 and DELFIN.

Key Words: *Bacillus thuringiensis*, Efficacy, *Chilo partellus*, Bioassay

Maize (*Zea mays* L.) is an important cereal crop which serves as staple food for millions in the world. It is important cereal crop of Punjab having an area of 129 thousand hectares with a production of about 475 thousand tonnes during 2013 (Anonymous, 2014). One of the major factors for the poor maize yield is the insect pest complex as it is attacked by 130 species of insects (Sarup *et al.*, 1987). Among these insect pests, maize borer, *Chilo partellus (Swinhoe) is economically important pest attacking summer maize*. Under Punjab conditions, it is reported to cause 57.70 to 79.40 per cent losses in grain yield (Singh & Sajjan, 1982). Various methods of control of *C. partellus* have been developed to check its damage to maize crop and there have been more emphasis on chemical control. Insecticides cause environmental pollution, residues, development of resistance, pest resurgence. So, an alternative to chemical control is biological control which is a crucial part of integrated pest management. Insecticides based on *Bacillus thuringiensis* formulations are highly specific in their action, safe and effective in control of wide spectrum of agriculture-pests (Mazid *et al* 2011). Therefore, present study was done to screen *Bacillus thuringiensis* isolates for its high insecticidal activity at minimum concentrations against *C. partellus* in maize.

MATERIAL AND METHODS

Five standard isolates of *Bacillus thuringiensis* viz. MTCC 868, MTCC 4715, 4D4, 4J3 and PDBC Bt-1 were procured from different sources. All these isolates were maintained at refrigerated temperature on T3 media. Two commercial formulations of *Bacillus thuringiensis* var. *kurstaki* i.e. DELFIN and LIPEL manufactured by Cetris, USA and Agrilife, SOM Phytopharma (India) limited, respectively were also evaluated alongwith untreated control.

Preparation of spore crystal complex: The spore-crystal toxin (SCT) was produced as per the method of Salama *et al.* (1981) and Dulmage *et al.* (1970) with little modification. The inoculum was prepared by transferring a loopful of cells from nutrient agar slants into 50ml of Luria medium. After overnight incubation at 30±2°C at 200 rpm, the growth was inoculated into culture flasks containing T3 medium. One ml of the overnight culture was inoculated into 250ml flasks containing 100 ml of the above media. The flasks were fermented at 30±2°C at 200 rpm on shaker incubator for three days. After that crystal mixture was harvested in pellets by centrifugation. The pellet obtained from 1 litre of culture was re suspended in lactose solution and the mixture was stirred. Then, the high purity acetone (4 volume) was added with stirring to a final volume of 1 litre. The mixture was filtered through Whatmann Filter paper to collect the precipitate containing spores and crystals. The dried powder was then suspended in 100ml of CMC-Triton X-100 .The protein content was estimated as per the method of Lowry *et al.* (1951).

Collection and rearing of *Chilo partellus:* Maize borer, *C. partellus* (Swinhoe) larvae were collected from infested maize and sorghum fields and were reared on artificial diet under laboratory conditions. The second and third instar larvae of *C. partellus* reared on artificial diet were used for bioassay studies. The spore crystal complex of five *Bacillus thuringiensis* isolates and isolates obtained from two commercial formulations at three different concentrations were evaluated against second and third instar larvae of C. *partellus* along with untreated control. There were eight

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treatments with three replications and ten larvae per replicate.

Insect Bioassay: The crystal toxin complex was inoculated to the test insect larvae by incorporating it into the agar based diet while still in the liquid state (Seshu Reddy and Davies, 1979). Ten milliliter of freshly prepared artificial diet was poured in 50 ml glass or plastic vials. One milliliter of different concentrations of spore crystal toxin (SCT) complex viz. 125, 250 and 500µg/ml was inoculated in diet before solidification. The larvae previously starved for 10 minutes were then individually transferred to each inoculated vial and incubated at room temperature (20-28° C). Untreated controls without any crystal suspension was run simultaneously. The larvae were observed daily for mortality and cumulative mortality was recorded upto 10 days.

RESULTS AND DISCUSSION

Second instar: The mortality of second instar larvae of C. *partellus* was very low and non-significant upto two days of treatment. After three days of exposure, mortality ranged from 2.22 to 20.00 per cent. Maximum mean cumulative per cent mortality was recorded in commercial formulation DELFIN isolate which was at par with isolates MTCC 4715, 4D4 and commercial formulation LIPEL isolate (Table 1). After seven days of exposure, maximum mean cumulative mortality (56.66%) was recorded in 4D4, which was at par with DELFIN (56.66%). This was followed by isolate MTCC 868 and was at par with isolate 4J3, MTCC 4715 and commercial formulation LIPEL SP. However, minimum mean cumulative mortality of 16.66 per cent was recorded in PDBC Bt1. After ten days of exposure, maximum mean cumulative mortality (82.22%) was recorded in 4D4, which was at par with DELFIN (78.88%) and MTCC 868 (76.66%). Among various concentrations, maximum mean larval mortality (68.88 %) was recorded in highest concentration i.e. 500µg/ml and it was significantly better than both the concentrations viz. 250 and 125µg/ml which recorded 64.81 and 57.03 per cent mortality, respectively (Fig 1).

Third instar: After three days of exposure, all the treatments gave significantly higher mortality than control (4.44%). Maximum mean cumulative mortality (15.55%) was in isolate MTCC 868 being at par with all the isolates viz. 4D4, PDBC Bt-1, 4J3, DELFIN and LIPEL SP. However, minimum mortality was in isolate MTCC 4715 (8.88%). After seven days of exposure mean cumulative per cent mortality was maximum (50%) in MTCC 868 which was at par with 4D4 (43.33%) and Delfin (41.11%). After ten days of exposure, cumulative mean per cent mortality was maximum (75.55%) in MTCC 868 which was at par with DELFIN and 4D4 followed by commercial formulation LIPEL which was at par with MTCC 4715 Minimum mean cumulative percent mortality was recorded in isolate PDBC Bt-1 (52.22%) (Table 1). Among various concentrations, maximum mortality was recorded at higher concentration (Fig 1).

It can be concluded that among all seven *B. thuringiensis* isolates 4D4and MTCC 868 were most potent isolates against second and third instar larvae of *C. partellus* which recorded maximum mortality and were at par with DELFIN. Further, it was found that mortality at higher concentration (500µg/ml) was significantly better than middle concentration (250µg/ml) which in turn was significantly better than the lower concentration (125µg/ml) (Fig 1).

The present findings corroborates the earlier results

Table 1. Laboratory evaluation of *Bacillus thuringiensis* isolates against second instar and third instar larvae of *C. partellus*

Treatment	Cumulative per cent mortality of *C. partellus*					
	Second instar larvae			Third instar larvae		
	3 days	7 days	10 days	3 days	7 days	10 days
4J3	8.88 (15.43)	43.33 (41.01)	65.55 (54.28)	12.22 (20.23)	38.88 (38.51)	56.66 (48.85)
PDBC Bt-1	2.22 (4.79)	16.66 (22.20)	28.88 (32.32)	12.22 (20.23)	24.44 (29.43)	52.22 (46.29)
MTCC 868	11.11 (18.28)	45.55 (42.39)	76.66 (61.42)	15.55 (22.77)	50.00 (45.00)	75.55 (60.52)
MTCC 4715	18.88 (25.48)	42.22 (40.34)	66.66 (54.85)	8.88 (15.43)	40.00 (39.06)	65.55 (54.52)
4D4	15.55 (22.77)	56.66 (49.24)	82.22 (66.82)	14.44 (21.21)	43.33 (41.08)	73.33 (59.28)
LIPEL	13.33 (21.13)	45.55 (42.39)	74.44 (59.85)	12.22 (20.23)	37.77 (37.35)	67.77 (55.63)
DELFIN	20.00 (26.22)	56.66 (49.99)	78.88 (63.07)	12.22 (19.18)	41.11 (39.82)	74.44 (59.78)
Control	0.00 (0.90)	14.44 (21.87)	22.22 (27.63)	4.44 (8.49)	16.66 (22.30)	28.88 (32.32)
CD (p=0.05)	(5.50)	(6.33)	(5.65)	(5.98)	(5.24)	(4.49)

Values in parentheses are arc sine transformations

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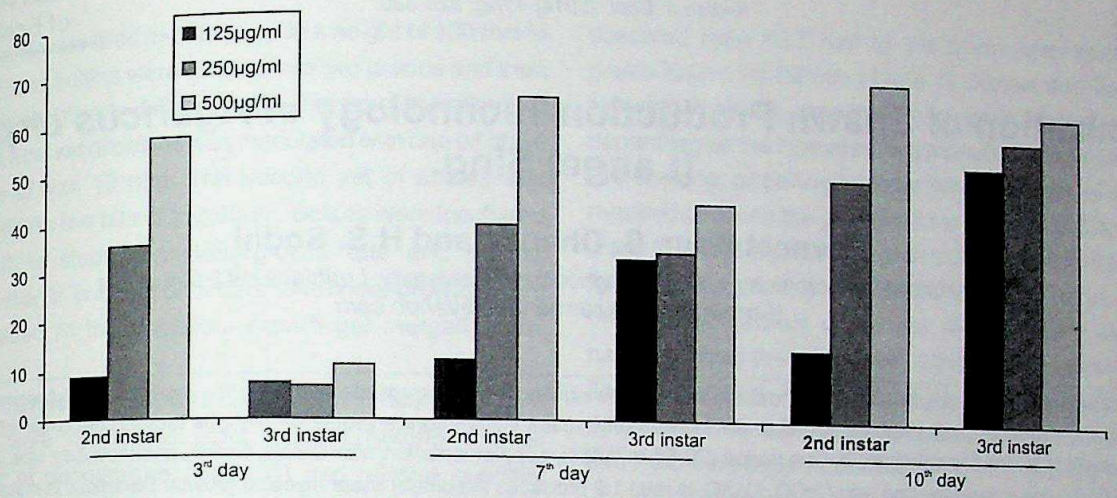

Fig 1. Efficacy of *Bacillus thuringiensis* Spore Crystal Toxin Complex (SCT) for the control of second instar and third instar larvae of *Chilo partellus* at different concentrations

of Kimani *et al* (2010) who observed that two isolates Bt 44 and Bt 48 were the most potent against first instar larvae of *C. partellus*. Opondo *et al* (2010) isolated three *B. thuringiensis* isolates from soil samples and reported that these isolates showed different toxicity to the larval stages of *C. partellus* with isolates 1M exhibiting the highest toxicity of specificity (Pigott and Ellar, 2007).

In the present investigation, it was observed that the per cent mortality was very low and non-significant upto two days of exposure. This might be due to the fact that *B. thuringiensis* being stomach poison, when enters into the midgut of insect, it gets dissolved in the alkaline pH, releasing endotoxins (Schnepf*et al*., 1998) thereby killing the insect. Present results showed that with increase in concentration there is increase in mortality. Therefore, there is direct relationship between increase in concentration and mortality. Mortality at higher concentration (500µg/ml) was significantly better than middle concentration (250µg/ml) which in turn was significantly better than the lower concentration (125µg/ml) when evaluated against both 2nd and 3rd instar larvae of spotted stem borer, *Chilo partellus* (Swinhoe). Kamala and Padmavathamma (1997) reported that the per cent larval mortality in all the instars of *B. mori* was higher at higher concentrations of *B. thuringiensis*.

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Optimization of Spawn Production Technology of *Agaricus bisporus* (Lange) Sing.

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Abstract: The present investigation was carried out to improve the existing technology of spawn production technology of *Agaricus bisporus* (Lang) Singh to produce quality spawn with high yield potential to make this venture a profitable. Various factors that could affect spawn mycelial growth rate are the substrate boiling period (20-50 minutes), supplementation with $CaCO_3$:$CaSO_4$ and inoculum size. The grains boiled for 30 minutes supplemented with $CaCO_3$:$CaSO_4$ in ratio 1:2 produced maximum linear mycelial growth. Beneficial in mycelial growth rate was observed by using one and two bits of inoculum with two bits of culture. Yield data after four weeks of harvest gave 10.5 -15.25 kg mushrooms per quintal compost.

Key Words: *Agaricus bisporus*, Spawn Supplement, Spawn Age, Yield Potential

Agaricus bisporus, the white button mushroom is an important cultivated variety grown with 35-40% share in the world production. The process of mushroom cultivation involves selection of an acceptable mushroom species/development of active spawn, preparation of selective substrate/compost, care of mycelial (spawn) running, management of fruiting/ mushroom development and harvesting mushrooms carefully. Failure to achieve a satisfactory harvest may often be traced to unsatisfactory spawn. The process of spawn production is a technical process and requires a lot of experience and specialized knowledge and care (Chinda and Chinda, 2007). It has been estimated that 15-20 per cent of commercial spawn is lost due to contamination by bacteria, fungi, or actinomycetes every year. The availability of the quality of spawn, free from contaminants is the most critical factor in boosting the mushroom production. Most of the grains are good substrate for spawn preparation of *A. bisporus*. Reddy *et al.* (2013) carried out spawn production of *A. bisporus* by using sorghum grains. There is a need to improve upon the existing technology to obtain pure culture at minimum incubation period with minimum loss due to contamination. During the process of spawn production, selection of raw material and their disinfection is very important. Therefore, boiling and soaking of grains, addition of calcium carbonate and calcium sulphate and sterilization of substrate assumes special significance. Although protocol for spawn preparation has been standardized yet a problem of high rate of contamination could make it non- profitable. Present study has been planned to standardize the existing spawn preparation protocol in order to minimize the rate of contamination and to obtain maximum biological efficiency.

MATERIAL AND METHODS

Agaricus bisporus strain U3 was procured from Mushroom Research Lab, Department of Microbiology, Punjab Agricultural University, Ludhiana. The culture was grown on Potato Dextrose Agar (PDA) medium at 25± 1°C. Wheat grain spawn was prepared using the standard methodology of Garcha (1997). Three wheat grain varieties (PBW 343, PBW 621 and HD 2967) were used to prepare spawn to study the effect of boiling period on the mycelial growth; grains were boiled for 20-50 minutes. The boiled grains were then mixed with gypsum ($CaSO_4.2H_2O$, Lab grade) and chalk powder ($CaCO_3$) @ 2 and 4% w/w, respectively. These grains were then filled in the spawn tubes (25 mm×198 mm) to a height of approximately 120 mm, autoclaved at 20 ± 1 lbs for 90 min. After overnight cooling, each tube was inoculated aseptically with mycelial bits of size 10 mm of standard inoculum (15 days old) of A. bisporus U3, incubated at 25+1°C and linear growth was measured periodically at 3 day interval till complete impregnation for a period of 33days.

To study the effect of supplementation with calcium carbonate and gypsum on the mycelial growth rate, boiled and cooled grains were supplemented with three different ratios of $CaCO_3$ (chalk powder) and $CaSO_4$ (gypsum) i.e., 1:1 (30g: 30g) 1:2 (20g: 40g), 2:1 (40g: 20g) and filled in spawn tubes, autoclaved, inoculated with culture and incubated at 25+1°C to measure linear growth periodically at 3 day interval till the complete impregnation of the grains upto a period of 33days as above.

Agaricus bisporus is a slow growing mushroom. There is a need to obtain pure culture at minimum incubation period with minimum loss due to contamination. Boiled,

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mixed grains were filled in bottles up to a height of 100 mm in bottles. These bottles were divided into two groups and then inoculated aseptically with mycelial bits from the standard inoculum. First set of bottles was inoculated with one bit of the mycelium of size 10 mm. The second set of bottles was inoculated with two bits of mycelium. Bottles were incubated at 25±1°C to study mycelium growth rate and rate of contamination in both set of bottles. The linear growth in mm was recorded till the mycelium growth get merged in the bottles

Cultivation study: Cultivation trials using *A. bisporus* were conducted indoor under natural climatic conditions of temperature (14-22°C) and relative humidity (70-90%) at the University Mushroom Research Complex using standard methodology (Garcha, 1997). The observations were made on the period taken for case run, pinning, and first harvest after spawning, yield (kg quintal^{-1} compost) and no. of fruit bodies along with average weight of a fruit body.

RESULTS AND DISCUSSION

Effect of wheat variety and boiling period on mycelial growth of *Agaricus bisporus:* A periodic increase in linear mycelial growth was observed from 18.3 mm upto 117.3 mm from 3-33 days incubation at 25±1°C. There was no significant variation among the wheat varieties indicating that any of the three varieties can be used for the preparation of the mushroom spawn.

A gradual increase in linear mycelial growth was observed from 12.7 mm to 118.3 mm with maximum on grains boiled for 30 min (Table 1). Royse *and* Zaki (1991) reported that the preparation of grain spawn may vary depending on the type of spawn manufacturing system used. Pre-cooking, or boiling in water for 20-30 min, of millet was required because the grain tends to become soft and sticky if water is added immediately prior to sterilization. Pre-cooking, followed by coating the millet with 2-3% (dry weight) precipitated calcium carbonate (PCC) before sterilization had minimized the stickiness of the grain to provide a more flowable product. Rye grain, on the other hand, had a much thicker seed coat so precooking was not required and water and PCC were added immediately before sterilization.

Effect of calcium carbonate and calcium sulphate on spawn preparation: Out of three ratios of $CaCO_3$ and $CaSO_4$ (1:1(30g: 30g) 1:2 (20g: 40g), 2:1 (40g: 20g), maximum linear mycelial growth was observed when 1:2 ratio, whereas other two ratio showed no significant variation in linear mycelial growth (Table 2). Khan *et al.* (1991) reported that a combination of 2 per cent gypsum and 6 per cent lime added to the wheat grain was best for spawn production of *Agaricus bisporus*. Spawn production studied by Pandey (1998) revealed that the addition of chalk powder and gypsum decreased the stickiness of grains, made them free flowing besides decreasing the incidence of bacterial contamination, which is important in commercial spawn production. The linear mycelial growth was found fully covered in 12 days when 2 bits were inoculated, whereas it took 21 days for complete impregnation when one bit was used (Table 3).

Table 1. Effect of different boiling periods on the mycelial growth of *Agaricus bisporus*

Boiling period (min)	Linear mycelial growth (mm) at different incubation periods (days)					
	3	6	12	18	24	30
20	12.7	18.7	31.3	45.0	57.3	72.3
30	20.3	31.0	50.7	67.7	88.6	109.0
40	17.6	25.7	45.3	63.3	80.3	96.3
50	16.7	24.3	40.3	56.6	74.7	91.3
CD (0.05)	2.55	2.30	2.54	2.30	2.17	2.66

Table 2. Effect of $CaCO_3$: $CaSO_4$ ratio on mycelial growth of *Agaricus bisporus*

Additives $CaCO_3$:$CaSO_4$	Linear mycelial growth (mm) at different incubation periods (days)				
	6	12	18	24	30
1:1(30:30g/1000g)	22.7	36.3	50.7	65.0	80.7
1:2(20:40g/1000g)	30.3	39.3	67.7	88.3	107.0
2:1(40:20g/1000g)	21.6	26.7	51.3	67.7	81.7
CD (0.05)	4.47	4.57	4.32	4.11	2.75

Table 3. Effect of inoculums size on mycelial growth of *Agaricus bisporus*

Inoculum size	Linear mycelial growth (mm) at different incubation periods (days)						
	3	6	9	12	15	18	21
1 bit of inoculum	14.3	27.0	41.0	53.3	69.3	83	mycelium merged
2 bits of inoculum	28.0	53.7	79.6	mycelium merged	-	-	-
CD (0.05)	2.4	2.6	3.7	-	-	-	-

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Yield evaluation of *Agaricus bisporus* U3 spawn produced under standardized conditions: *A. bisporus* spawn bottles were used for sowing after 10, 20, 30, 40 days of incubation wheat straw based compost. The case run took 17-22 days while pinning started 37-42 days after spawning (Table 4). First harvest was made 40-45 days of spawn run. Yield data after 4 weeks of harvest gave 10.5 -15.25 kg mushrooms per quintal compost.

Table 4. Effect of spawn age on the yield potential of *Agaricus bisporus*

Spawn age (d)	Case run weight (d)	Pinning after spawning (d)	First harvest after spawning (d)	Yield (kg q^{-1} compost)	No. of fruit bolls	Average weight of FB (g)
10d	19	39	43	13.00	1252	10.3
20d	17	37	40	15.25	1048	14.5
30d	19	39	42	13.50	1400	936
40d	22	42	45	10.50	885	11.8
CD (0.05)				0.72	112	

Maximum yield was harvested when G1 spawn after 20 days of incubation was used for sowing. The yield from 10 day and 30 day spawn was at par, while it was lowest in 40 day old spawn. The number of fruit bodies ranged between 885-1252 with maximum from 30 day old spawn. Average weight of fruit body was between 9.6 – 14.5 g with maximum from 20 day old spawn harvest. No disease incidence was recorded in the crop sown with 10 and 20 day old spawn, whereas *Coprinus* and green mould was recorded from 30 d and 40 d old spawn crop harvest. The observations suggested that 20 day old spawn could be used for maximum harvest (Table 4). Pani (2011) reported that the increase in spawn age beyond 21 days reduced the number of sporophores, which could have been due to apparent loss of vigor and viability of fungal mycelia. Two month old spawn sustained the least weight of sporophores but supported maximum individual weight of fruiting body.

Present investigation had shown that any of the wheat variety can be used as substrate for the preparation of the spawn. The grains should be boiled for 30 min, supplemented with $CaCO_3$:$CaSO_4$ in 1:2 ratio. Use of two bit culture was beneficial for early impregnation of grains in 12 days in two bit culture, whereas, it took 21 days in one bit culture at temperature 25°C. Yield harvested was maximum (15.25 kg q^{-1} compost) in 20 day old spawn prepared under conditions optimized during the present study.

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Physico-Chemical and Phycological Profile of River Pandu at Kanpur

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Abstract: River Pandu flowing on the southern outskirts of Kanpur is severely subjected to anthropogenic stress all along its stretch passing through Kanpur. Municipal and industrial wastes of the southern Kanpur is disposed into it without any pre- treatment, which is likely to adversely affect its physico-chemical and phycological profile. The river was investigated during 2009-2010 revealed that discharge of wastes in to the river adversely affected its water quality and algal profile. Water quality was adversely affected in terms of transparency and dissolved oxygen, which were quite low while colour, total solids, B.O.D. and nutrients were quite high indicating the eutrophic nature of water. Water had detectable amounts of heavy metals specially Cu^{+2}, Cr^{+6} and Zn^{+2}. Only 30 genera and 42 species were recorded. Algal profile of the river at different stations lacked consistency of results due to fluctuating quality and quantity of wastes discharged. Low diversity and similarity index values reported are indicative of an unhealthy and stressed ecosystem.

Key Words: Anthropogenic Stress, Waste Effluents, Algae, River Pandu, Kanpur

River Pandu- a wee tributary of river Ganga, owes its provenance from the pumped storage of Lower Ganga Canal approximately 110 kilometers north-west of Kanpur. It flows on the southern outskirt of Kanpur through Panki Industrial Estate (PIE) covering a distance of about 64 kilometers before its confluence with river Ganga in south-west of Kanpur in Fatehpur district. During its course through Kanpur, five major drains carrying sullage water, sewage and industrial effluent discharge their wastes in to it without any pre-treatment (Tiwari, 2004; Tiwari and Bajpai, 2011). Lean flow of the river does not permit enough dilution of the pollutants to permit natural purification of the river to the desired extent, which is likely to affect the phyco-diversity of the river. Hence the present study was undertaken to assess its physico-chemical and phycological profile at its Kanpur stretch.

MATERIAL AND METHODS

Material sampling was done approximately half kilometer downstream of five major outfalls discharging waste into it and sixth sampling station, just half kilometer upstream of its confluence with river Ganga at Fatehpur district during 2009-2010. The major outfalls are Thermal Power Plant drain, Panki Municipal drain, Ganda Nala, Halwa Khanda drain and Central Ordinance Depot (COD) drain. Sampling stations on the river were Tikra village, Panki Industrial Area, Mardanpura, Meharbanpura, Hamirpur Road Bridge and Sher Shah Suri bridge. Effluent, water and algal samples were collected and analyzed for qualitative and quantitative estimation of the pollutants and algae as per standard procedure (APHA, 1989). Samples were collected in thoroughly cleaned plastic bottles and were transported to the laboratory for qualitative and quantitative analysis. Algal cell number was estimated using Sedgewick-Rafter Counting cell (SR Counting Cell) and results have been expressed as number of individuals per liter after applying the appropriate correction factor. Algal identification was done with the help of pertinent literature on algae (Desikachary, 1959; Smith, 1950; Tiffany and Britton, 1952). Algal diversity was computed using standard indices (Shannon-Weaver 1963, Margalef, 1958). Taxonomic similarity was computed following Sorenson (1948).

RESULTS AND DISCUSSION

Results of the physico - chemical investigation of the waste effluents and river water are depicted in Table 1 and 2. River is a shallow river with a depth ranging from 1-2.5 meters but also has a few interspersed deeper zones of about 4 meters. Except a few small portions where the river bed is rocky and composed of small pebbles, it has a muddy bottom. River discharge fluctuates in between 3240-5450 m^3 per hour. River flows with a slow velocity that ranged from <0.01m^{-s} to 0.07 m^{-s}. Peak velocity was noticed in September and minimum in June.

Colour: Colour of the waste effluents varied widely ranging from light brown, red brown, blue, blackish brown to light black or murky. The qualitative as well as the quantitative variations in the effluent characteristics may be

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Table 1. Physico-chemical characteristics of waste effluents of drains

Parameters	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
Present status	Untapped	Untapped	Untapped	Untapped	Untapped	
Colour	Murky black	Murky black/Red brown	Murky	Black	Murky black	*
Odour	foul	Organic/pungent	Faecal foul	Faecal foul	Faecal foul	*
pH	7.7	8.6	7.9	7.9	8.3	
Temp. °C	34	36.2	37.4	33	32.4	
Transp.	Nil	Nil	Nil	Nil	Nil	
Total solids	1699	1308	1254	1112	760	
Suspended solids	1540	183	251	200	70	100
Dissolved oxygen	Nil	Nil	Nil	Nil	Nil	
$B.O.D._{5}$	141	202	229	180	130	30
C.O.D.	304	440	475	302	271	250
Nitrate	Nil	Nil	Nil	Nil	Nil	
Ammonia	143.4	205	107.6	151.6	136.6	50
Urea	Nil	1.6	Nil	Nil	Nil	
Chloride	125	175	285	178	140	1000
Phosphate	1.6	2.4	4.4	1.8	2.2	5
Oil and Grease		+	+	+	+	

All values in mg l^{-1}except colour, odour, temperature (°C) pH and transparency (cm)
+ Presence, - absence * all efforts should be made to remove colour and odour as far as possible

Table 2. Physico-chemical characteristics of the river water at different stations (n=12)

Parameter	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
Colour	Murky	Murky Black	Murky black	Murky	Muddy	-
Odour	Nil	Foul	Faecal foul	Faecal foul	Nil	-
Temperature	25.3	27.8	25.7	26.8	25.6	27.1
Transparency	17.2	2.3	6.2	7.3	15.4	13.7
Total solids	121	934	587	830	417	469
pH	7.8	8.2	8.5	8.3	8	8.2
Total alkalinity	110.0	159.6	270.6	211.7	145.8	138.0
D.O.	5.5	2.4	1.8	2.3	3.7	4.1
$B.O.D_5$	10.3	39.5	45.2	67.1	44.4	30
C.O.D	20.3	220	165	144	69	23.7
Chloride	25.5	80.7	62.6	75.4	54.9	45
Total hardness	135	366	457	599	387	517
Ammonia	0.46	3.64	18.6	9.95	8.92	2.0
Nitrate	0.15	0.05	0.02	0.09	0.13	1.28
Phosphate	0.24	1.72	1.76	1.86	1.44	1.22
Sulphate	0.78	5.3	4.4	12.5	3.66	4.6

Values in mg l^{-1}l except colour, temperature (°C), odour, transparency (cms) and pH

attributed to varied chemical and technical processes used in different industries, effluent of different industries in different drains and also to the relative proportion of the municipal and industrial wastes carried by them. A critical perusal of the data pertaining to effluent characteristics with prescribed ISI standards (IS: 1981) for wastes to be discharged into surface waters revealed that most of the parameters were either beyond or approaching the permissive limits. Discharge of these wastes in to the river adversely affected the river water quality as is obvious from the water quality gradients depicted in Table 3. Coloured water, low transparency, low dissolved oxygen coupled with significantly high values of BOD, COD, hardness, chloride, ammonia and phosphate all indicated the oxygen stressed polluted condition of the river. Except station 1, all the downstream stations were heavily polluted. The impact of this anthropogenic stress was also evident on the algal community of the river (Table 3-5).

An important factor affecting chemical reactions

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Table 3. Phyco-Profile of the river

Algae	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
Cyanophyceae						
Anacystis sp.	+	-	-	-	-	+
Merismopedia minima	+	-	-	-	-	+
Microcystis sp.	-	-	-	+	-	+
Nostoc sp.	+	-	-	-	-	-
Oscillatoria tenuis	-	+	+	+	+	-
Oscillatoria limosa	-	+	-	+	-	+
Oscillatoria princeps	+	-	-	+	+	-
Oscillatoria sancta	+	-	-	+	+	+
Oscillatoria curviceps	+	-	-	-	-	-
Phormidium tenue	+	+	+	+	+	-
Phormidium uncinatum	+	+	+	+	+	+
Chlorophyceae						
Actinastrum sp.	+	-	+	+	-	+
Ankistrodesmus sp.	-	+	-	+	+	-
Chlamydomonas sp.	-	-	+	+	+	+
Chlorella vulgaris	+	+	-	+	+	-
Cladophora glomerata	-	+	+	+	+	-
Closterium sp.	+	-	+	+	+	-
Coelastrum sp.	+	-	-	-	-	-
Hydrodictyon reticulatum	+	-	+	-	-	+
Pandorina morum	-	+	+	+	+	-
Pediastrum boryanum	+	-	-	-	-	-
Pediastrum duplex	+	-	-	-	-	-
Pediastrum simplex	+	-	-	-	-	+
Pediastrum tetras	+	-	-	-	-	+
Scenedesmus quardicauda	+	+	+	+	-	+
Scenedesmus abundans	+	-	-	-	-	+
Spirogyra sp.	+	-	+	+	+	+
Stigeoclonium tenue	+	+	+	+	-	+
Zygnema sp.	+	-	-	-	+	+
Bacillariophyceae						
Achnanthes sp.	+	-	-	-	-	-
Asterionella sp.	+	-	-	-	-	+
Cyclotella sp.	+	-	-	-	+	+
Cymbella sp.	+	-	-	-	-	+
Diatoma elongatum	+	-	-	-	-	+
Fragilaria pinnata	+	-	-	-	-	-
Fragilaria capucina	+	-	-	-	-	-
Melosira granulatum	+	-	+	+	+	-
Navicula cryptocephala	-	+	+	+	+	+
Navicula cuspida	+	+	-	-	-	+
Nitzschia palea	-	+	+	+	+	+
Nitzschia acicularis	+	-	-	+	+	+
Pinnularia appendiculata	+	-	-	+	+	-
Synedra sp.	-	+	-	+	+	-
Tabellaria floculosa	+	-	-	+	-	-
Euglenophyceae						
Euglena sp.	-	+	-	-	+	-
Phacus sp.	+	+	+	+	+	+

+ Denotes presence; -denotes absence

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occurring in an aquatic ecosystem as well as on the soil water interphase is well within the biokinetic range of 10-45°C. Transparency ranged from 2.3 to 17.2 cms. Low water transparency as a result of huge waste discharge adversely affected the euphotic zone of the river and consequently the algal population and diversity.

Total solids and H^+ Ion concentration (pH): Total solids (suspended and dissolved) contributed by carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of Ca, Mg, Fe, Mn and other compounds exerted a pronounced effect on osmoregulatory phenomenon of aquatic phototrophs and also adversely affected transparency of the river water. Low transparency as shown above may be attributed to this fact. The total solids in the river ranged from 121 mg l^{-1} to 934 mg l^{-1}. pH serves as an important index of nature and intensity of pollution. The pH of the river water at different stations ranged from 7.8-8.5 and was suitable for propping the algal growth. pH values are indicative of alkaline nature of the water as is obvious from the reported alkalinity values ranging from 110-270.6 mg l^{-1}. Minimum at station 1 and maximum value reported at station 3.

D.O. and B.O.D.: D.O. of the river water at any point is a tell-tail sign of the nature and intensity of pollution. Low D.O. (<4 ppm) and high B.O.D. (>2 ppm) at downstream stations 2-6 is an indication of anthropogenic pollution stress on the river. At times nil D.O. was reported at stations 2 and 4 in the months of May and June respectively (Table 2) indicating that at these stretches anoxygenic conditions prevailed for a short while. Invariably high ammonia and low nitrate values in the river water further insinuate the oxygen stressed condition of the river.

Nutrients and heavy metals: River is rich in nutrients as is obvious from the reported values of nitrate, ammonia and phosphate (Table 2). Nitrate content ranged from 0.02 to 1.28 mg l^{-1}, whereas ammonia concentration varied from 0.46 to 8.95 mg l^{-1}. A significant inverse correlation (r= -0.815) has been noticed between nitrate and ammonia content of the river. Low nitrate content of the river as compare to ammonia content further affirms the oxygen stressed condition of the river, which hampered the natural oxidation of ammonia in to nitrate. Phosphate concentration ranged from 0.24 to1.86 mg l^{-1} at different stations of the river. Thus, it is apparent that nutritional status of the river was quite suitable for propping the algal flora. Heavy metals reported in the river water include Cu^{+2}, Ni^{+2}, Pb^{+2}, Zn^{+2} and Cr^{+6}. Their respective concentration at each station is depicted in Fig.1. It is evident that Cu^{+2} was the most dominant metal followed by Cr^{+6} and Zn^{+2}

Algal profile: Algal profile of the river is depicted in Table 3, whereas, quantitative data pertaining to its abundance, species number, and diversity values are given in Table 4. Table 5 depicts the coefficient of similarity values between the algal profiles at different stations. Despite the nutrient rich water, low algal diversity and population of the river may be attributed to the presence of toxic materials in water. Maximum species number was recorded at station 1 (35), which drastically declined at station 2 (16) and 3 (16) and could not reach at par to station 1 till station 6. Chlorophyceae outnumbered the other algal groups in species representation but so far as the numerical strength is concerned cyanophyceae and bacillariophyceae dominated the other groups.

Algal diversity values computed for the present study also indicated the adverse impact of effluent discharged on river algae (Table 3). Maximum values were recorded at station 1. Values declined sharply at stations 2 and 3 and remained quite low at rest of the downstream stations. It is evident from the table that not only the species number but algal population too declined sharply at stations 2 and 3 as compared to station 1. At rest of the downstream stations, it was slightly better than station 1. This may be attributed to certain obvious reasons such as low transparency and reduced illumination as a consequence of residual fly ash discharged by Panki Thermal Power Plant drain upstream of station 2 and discharge of coloured industrial effluent from Panki municipal drain upstream of station 3 and presence of heavy metals in the effluents (Fig. 1). These factors probably acted synergistically declining the algal growth and diversity. The present findings are in agreement with some earlier reports on the same river (Handa *et al.*, 1985; Tiwari, 2006). Albeit domestic sewage is also discharged via these drains in to the river but probably its growth-stimulating effect on algal population was nullified by the presence of heavy metals coupled with low transparency of water at these stations. As river flowed downstream, toxicants got diluted in due course of time and natural

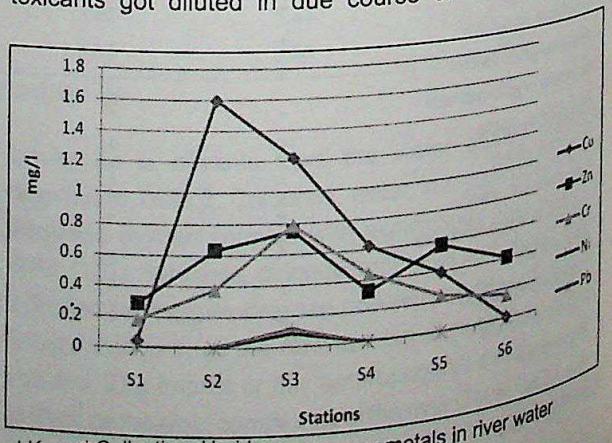

Fig. 1. Concentration of heavy metals in river water

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Table 4. Algal individuals l^{-1} (n=24) species number and diversity values at different stations

	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
No of individuals	174	63	73	199	339	336
No of species	35	16	16	25	22	25
Shannon-Weaver Index	4.41	1.73	1.68	2.49	2.09	2.96
Margalef Index	3.95	1.06	1.18	2.08	1.44	1.93

Table 5. Cofficient of taxonomic similarity among different stations

Stations	Tikra village	Panki industrial area	Mardanpura	Meharbanpura	Hamirpur road bridge	Sher Shah Suri bridge
S_1	-	0.27	0.39	0.52	0.44	0.66
S_2	-	-	0.63	0.63	0.58	0.41
S_3	-	-	-	0.73	0.63	0.51
S_4	-	-	-	-	0.68	0.54
S_5	-	-	-	-	-	0.44

removal of pollutants enhanced the euphotic zone. Further addition of sewage through other drains enriched the river water with nutrients. Thus reduced toxicity, improved transparency and nutrient enriched water triggered the algal growth at stations 4, 5 and 6 reaching a maximum of 339 individuals at station 5 (Table 3). But despite this the algal diversity as well as algal population in the river was quite low as compared to other perennial rivers of India. Out of total 46 species, 8 were reported exclusively at station 1 and were never reported from any other station. This shows that discharge of anthropogenic wastes in the river severely disturbed the ecosystem resulting in disappearance of more than 50% species at the very next downstream stations 2 and 3. At station 4, a few of them reappeared but the species number could not reach at par to station 1 till station 6. Highest taxonomic similarity (0.73) was recorded between stations 3 and 4 indicating that these stations had similar physico-chemical ambience. Lowest taxonomic similarity was recorded at stations 1 and 2 indicating that anthropogenic stress exerted a pronounced adverse effect on algal spectrum of the river. The study indicated that the river is under severe pollution stress and needs corrective measures to be adopted both at governmental and nongovernmental level so that it can be recuperated and saved from further deterioration.

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Performance of Yield Characters and Suitability for Pickling in Different Medicinal Coleus [*Plectranthus forskohlii* (Willd) Briq.] Genotypes

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Abstract: Studies were conducted on the performance of yield characters of ten medicinal coleus [*Plectranthus forskohlii* (Willd) Briq.] genotypes collected from different geographical locations. Among the genotypes evaluated for yield parameters maximum number of tubers per plant (20.20) recorded in KRCCH-7, while highest tuber length (20.68 cm) and tuber diameter (2.51 cm) was observed in genotype KRCCH-8, highest tuber density (1.97 cc) was observed in KRCCH-2, highest fresh weight of tubers per plant (417.67 g) was observed in KRCCH-1, highest dry weight of tubers per plant (56.05 g) was recorded in genotype KRCCH-3 and highest total dry matter accumulation per plant (205.20 g) was observed in genotype KRCCH-2. Among the genotypes evaluated for use as condiment, KRCCH-5 was found to be highly suitable.

Key Words: KRCCH , *Plectranthus forskohlii* (Willd) Briq.

Medicinal plants traditionally occupied an important position in rural and tribal lives of India and are considered as one of the most important sources of medicines since the dawn of human civilization. One such important medicinal plant is medicinal coleus [*Plectranthus forskohlii* (Willd) Briq.]. It is an ancient root drug recorded in Ayurvedic Materia Medica under the sanskrit name '*Makandi*' and '*Mayani*'. *Plectranthus forskohlii* [(Willd) Briq.] (*Coleus forskohlii* Briq.), belonging to the family Lamiaceae is an important medicinal plant indigenous to India. It is a perennial herb, popularly known as '*mainmool*' or '*makandiberu*' or '*mangani beru*' in the state of Karnataka and '*garmar*' in Maharashtra. It is distributed in subtropical Himalayas from Garwal to Nepal upto an altitude of 2500 m. The tuberous roots of medicinal coleus yield forskolin, a diterpenoid, which is used for glaucoma, asthma, congestive cardiomyopathy and certain cancers. It grows wild as an indigenous medicinal plant and the knowledge of its variability is an essential prerequisite for direct exploitation as a cultivar and indirectly as a base material for breeding programmes. Vegetative method of propagation adopted in this species for commercial cultivation heightens the prospects of utilizing the superior genotypes indentified in the present study. In this species, occurrence of wide genetic diversity in nature for tuber yield has been reported by Hegde (1992). Though there have been several earlier studies on evaluation of medicinal coleus not much progress has been achieved for its exploitation as a condiment. The present study was undertaken to assemble the variability in coleus for its utility as a condiment.

MATERIAL AND METHODS

Medicinal coleus genotypes were collected from different geographical locations in Karnataka state (Table 1). The unrooted cuttings from the terminal portion of each genotype were planted in polythene bags filled with 1:1 (v/v) mixture of well decomposed farmyard manure (FYM) and red soil. The cuttings were watered daily till 30 days in the nursery. The experiment was laid out in randomized complete block design (RCBD) with three replications and ten genotypes. The net plot size was 4.32 sq. m and provision was made for irrigation channels. After 30 days in the nursery, the rooted cuttings of each genotype were transplanted in the main field at a spacing of 60 cm x 45 cm. The polythene bags were removed without disturbing the root system and planted with minimum damage to the system. The plants were applied with recommended dose of fertilizers at 40 : 60 : 50 kg $N:P_2O_5:K_2O$ per ha in the form of urea, super phosphate and muriate of potash. Nitrogen was applied in split doses, 50 per cent nitrogen was applied as basal dose at the time of planting along with P and K and remaining 50 per cent of nitrogen was top dressed at 30 days after transplanting. Plant protection measures were taken up to control the pests and diseases.

Among ten genotypes of medicinal coleus, nine were used for pickle making, because of one genotype is

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non-tuberous type. The experimental design followed for the evaluation of pickles was completely randomized design (CRD). For pickling, tubers were harvested at 120 days after transplanting. The freshly harvested tubers of each genotype of coleus were washed and outer layer was peeled and cut into small pieces of 1.0 to 1.25 cm size and were pickled. The ingredients used for pickling were common for all the genotypes. The pickles so prepared were evaluated for organoleptic characters like taste and aroma, flavor and overall acceptability at 30 days after pickling on a five point hedonic scale (Ranganna, 1986).

RESULTS AND DISCUSSION

The yield components like number of tubers, tuber length, tuber diameter, fresh and dry weight of tubers varied significantly among the genotypes. Highest number of tubers per plant (20.20) was observed in KRCCH-7 genotype, whereas, tuber length (20.68 cm) and tuber diameter (2.51 cm) was in KRCCH-8 genotype and tuber density (1.97 cc) in KRCCH-2 genotype (Table 1). These variations are mainly attributed to the genetic makeup of these genotypes. The least number of tubers per plant (5.03) was recorded in genotype KRCCH-6, whereas, tuber length (10.16 cm) in genotype K-8, tuber diameter (0.56 cm) and tuber density (0.36 cc) was observed in genotype KRCCH-6. Highest total fresh weight of herbage (968.80 g) was observed in KRCCH-8 genotype, total dry weight of herbage (152.01 g) in KRCCH-6 genotype and per cent herbage dry matter (16.23) in KRCCH-5 genotype.

Highest fresh weight of tubers (417.67 g) was observed in KRCCH-1 genotype which was on par with KRCCH-3 and KRCCH-5 genotype (Table 2). This could be attributed to better vegetative growth parameters like plant height, plant spread, stem diameter, total number of branches and number of leaves. It is evident that, the yield of genotype is dependent on vigour of the plant. The genotype KRCCH-6 recorded highest plant spread, number of branches and number of leaves but tuber yield was very low, as it is a non tuberous type. Highest dry weight of tubers (56.05 g) was observed in KRCCH-3 genotype which was on par with KRCCH-1 and KRCCH-5 The variations in fresh and dry weight of tubers per plant among the different genotypes was mainly due to genetic makeup of these genotypes. The least fresh weight of tubers per plant (21.07 g) and dry weight of tubers per plant (3.13 g) was observed in non tuberous genotype KRCCH-6. Highest per cent tuber dry matter (17.53) was observed in KRCCH-6, tuber yield per plot (6.53 kg) in KRCCH-1 genotype, and total dry matter accumulation per plant (205.20 g) was in KRCCH-2 genotype. The highest tuber yield per hectare (15.31 t) was observed in genotype KRCCH-5 and was *on par* with KRCCH-1 and KRCCH-3 .

Organoleptic evaluation for the overall acceptability of pickles prepared from the nine genotypes revealed that pickles of genotype KRCCH-5 were highly acceptable. The factors that were found to influence the overall acceptability of the pickles seems to be its constituent factors like taste, aroma and flavour of the pickles. The genotype KRCCH-5 had significantly highest scores for taste and aroma (4.02), flavour (4.03) and overall acceptability (4.43) (Table 3).

In the present study, the highest tuber yield was registered in KRCCH-1, KRRCCH-3 and KRCCH-5 genotypes under Ghataprabha Left Bank Canal (GLBC) command area of Karnataka.

These genotypes can be used for further selections in the crop improvement programmes. High overall acceptability was recorded in genotype KRCCH-5 for use as condiment. Therefore, KRCCH-5 can be exploited by small scale cottage industries for pickling.

Table 1. Tuber characters, fresh weight, dry weight and per cent dry matter content of herbage in medicinal coleus genotypes at harvest (150 DAP)

Place of collection	Genotypes	Number of tubers/ plant	Tuber Length (cm)	Tuber diameter (cm)	Tuber density (cc)	Fresh weight of herbage (g/plant)	Dry weight of herbage/plant (g/plant)	Herbage dry matter content (%)
Hiriyur	KRCCH-1	18.80	12.59	2.48	1.83	833	108.02	13.60
Bastwad	KRCCH-2	14.80	13.62	2.36	1.97	891	141.23	15.07
UAS, Bangalore	Aisiri	14.53	12.34	2.16	1.58	786.67	115.10	13.73
Belgaum	KRCCH-3	16.67	13.11	2.22	1.54	689.07	98.94	15.05
Alarwad	KRCCH-4	15.53	13.81	2.46	1.78	452.07	71.35	15.75
Chikkodi	KRCCH-5	14.80	13.29	2.24	1.57	498.93	81.41	16.23
Arabhavi	KRCCH-6	5.03	12.24	0.56	0.36	931.73	152.01	15.98
Arabhavi	K-8	9.27	10.16	2.26	1.54	530.27	72.75	14.52
Madapur	KRCCH-7	20.20	12.15	2.37	1.64	678.93	100.47	14.77
Magihundi	KRCCH-8	10.20	20.68	2.51	1.69	968.80	133.47	13.33
	CD(p=0.05)	2.52	2.27	0.27	0.48	177.93	27.32	1.54

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Table 2. Fresh weight, dry weight, and per cent dry matter content of tubers and yield of medicinal coleus genotypes at harvest (150 DAP)

Genotypes	Fresh weight of tubers (g/plant)	Dry weight of tubers (g/plant)	Per cent dry matter content of tubers	Tuber yield (kg/plot)	Tuber yield (t/ha)	Total dry matter accumulation (g/plant)
KRCCH-1	417.67	53.75	12.73	6.53	15.18	172.11
KRCCH-2	315.60	44.01	13.19	4.70	11.59	205.20
Aisiri	224.53	30.70	14.06	3.90	9.10	144.15
KRCCH-3	399.87	56.05	12.91	6.23	14.48	151.28
KRCCH-4	330.80	45.25	13.59	4.70	10.98	117.11
KRCCH-5	398.47	51.27	12.44	6.30	15.31	130.02
KRCCH-6	21.07	3.13	17.53	0.33	0.76	148.36
K-8	124.53	16.88	13.39	1.73	4.09	89.63
KRCCH-7	322.18	45.38	13.32	5.30	12.34	147.18
KRCCH-8	321.47	36.10	12.65	5.40	12.65	185.37
CD(P=0.05)	54.90	5.49	1.86	0.91	2.05	26.52

Table 3. Sensory evaluation of medicinal coleus genotypes for pickles

Genotypes	Taste and aroma	Flavour	Overall acceptability
KRCCH-1	3.19	3.20	3.20
KRCCH-2	3.11	3.15	3.10
Aisiri	3.41	3.48	3.45
KRCCH-3	3.21	3.12	3.40
KRCCH-4	3.09	2.92	3.10
KRCCH-5	4.02	4.03	4.43
K-8	3.24	2.93	3.16
KRCCH-7	3.27	3.25	3.46
KRCCH-8	3.31	3.36	3.41
Mean	3.32	3.27	3.41
CD P=0.05)	0.30	0.23	0.19

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Comparative Yield Responses of Wheat Genotypes Under Sowing Date Mediated Heat Stress Conditions on Basis of Different Stress Indices

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Abstract: To evaluate the sensitivity or tolerance level of 24 wheat genotypes grouped in to early maturing genotypes (EMG) and late maturing genotypes (LMG) to heat stress, seven indices namely TOL, STI, stress susceptibility index, mean productivity, geometric mean productivity, relative performance and heat susceptibility index (HSI) were studied. Correlation coefficient analysis was performed between grain yield in timely and late sown environments with other yield indices. With respect to relative performance in yield components and HSI, EMG was characterized as tolerant to high temperature but it was found to be low yield potential group while LMG was found to be the sensitive group and high yield potential group. STI and GMP were found the strong indices which positively correlate with the yield under timely (Yp) and late (Ys) sown conditions in both the maturing groups and therefore these can be considered as a produced potential indices. In consideration of grain yield in timely and late conditions, different tolerance indices and correlation coefficient analysis on these traits, early maturing genotypes were selected for terminal heat stress tolerance.

Key Words: Early Maturity, Late Maturity, Heat Stress, Wheat, Yield Indices

Wheat productivity depended upon the joint effects of numerous factors. Major challenge facing modern crop production is maintaining crop yield under adverse stress environmental conditions. Wheat is the thermo-sensitive long day crop, the weather conditions during the growing season, especially the temperature, have a substantial influence on the plant metabolic processes, and thus on wheat quality (Patil *et al.*, 2003). Genetic diversity for heat tolerance in wheat is well established and varieties that show improved yield stability under heat stress have been identified (Hays *et al.*, 2007). High temperature stress during reproductive development result in a reduction in both individual kernel weight and kernel number. Terminal heat stress during anthesis and grain filling period, accelerate maturity and significantly reduces grain size and weight. One approach to dealing with these heat-related constraints is to improve wheat germplasm to provide higher tolerance to stresses associated with these environments. Many regions need wheat cultivars that are capable of high yields when the weather is beneficial but produce stable yields when conditions are adverse. These genotypes should have high yield potential in both favorable and high temperature environments. Yield and yield components in stress condition are still the most effective tools for stress evaluation The main objective of this study was to identify some improved wheat genotypes facing high temperatures during and after anthesis under field conditions that have high yield potential in both relatively favorable and high temperature environments.

MATERIAL AND METHODS

A set of germplasm consisting of various lines under the variable trial names (QTLs POPMAP G1-G9, CSIRO GCP G10-G12, SQ ELIT TD Sq G13-G16, PT CAN CAL II G17-G24) had been assembled by CIMMYT for evaluation for drought tolerance and heat tolerance under Generation Challenge Program. This germplasm was being evaluated in India at School of Agricultural Biotechnology and Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana for screening for drought tolerance under Punjab conditions. To observe the effect of terminal heat stress on these twenty four wheat genotypes, a field experiment was conducted with normal sowing (November 30) and late sowing (December 30) at the research field of Department of Botany, Punjab Agricultural University, Ludhiana, India. Plants in delayed sowing date experienced heat stress after anthesis. Studied genotypes had different growth durations and maturity periods. Hence on that basis, studied genotypes were further grouped in to two- early maturing (G1-12) and late maturing genotypes (G13-24). All the genotypes were planted in three replications, with a 5-row plot, row length of 2.5 m and 23 cm spacing between rows. Besides, the compact block was used to avoid soil

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heterogeneity effects and recommended agronomic practices for timely sown crop were followed to avoid moisture and other stresses so as to ensure proper expression of different traits. The genotypeswere compared for different attributes by estimating critical difference for each attribute. The various stress indices, relative performance (RP), heat susceptibility index (HSI), stress susceptibility index (SSI), stress tolerance index (STI), geometric mean performance (GMP), mean productivity (MP) and tolerance index (TOL) were measured by the following equation.

$$\text{Relative Performance (RP)} = \frac{\text{Grain weight per plant under stress conditions}}{\text{Grain weight per plant under normal conditions}} \times 100$$

$$\text{Heat Susceptibility Index (HSI)} = \frac{1 - yh/yn}{1 - yg/ya}$$

where, yh is mean yield of individual genotype under heat stress and yn under normal conditions and yg mean yield of all genotypes under high temperature and ya under normal conditions.

Stress Susceptibility Index (SSI) = ((1-(Ys/Yp))/SI

Susceptibility Index (SI) = $(\hat{Y}\ p\hat{Y}\ s)/p$

Mean Productivity (MP) = (Yp+Ys)/2

Tolerance Index (TOL)=Yp – Ys

Geometric Mean Performance (GMP) =Yp * Ys

Stress Tolerance Index (STI) = [Ys * Yp]/(Y p)²

Where, Yp indicates yield of a given genotype under favorable environment (less heated environment), Ys indicates yield of a genotype in unfavorable environment (more heated environment), *vp* indicates mean yield in favorable environment, and *vs* indicates mean yield in unfavorable environment. Least significant differences and coefficient of variation were calculated to compare the concurrent grain yield in more and less heated conditions and various indices were studied based on correlation matrix. LSD (0.05) represents the minimal difference between the genotypes which is statistically significant at the 5% level.

RESULTS AND DISCUSSION

The results on yield and yield indices of 24 wheat genotypes as influenced by sowing date mediated heat

Table 1. Cross identity and genotype identity along with their cross details of the genotypes

Genotype	CID	GID	Cross Name
G1	285851	4748166	BAV92/SERI
G2	285851	4748122	BAV92/SERI
G3	285851	5899052	BAV92/SERI
G4	285851	5899053	BAV92/SERI
G5	285851	4748051	BAV92/SERI
G6	285851	4748043	BAV92/SERI
G7	285851	4748041	BAV92/SERI
G8	7691	3895	SERI M 82
G9	8626	447649	BAVIACORA M 92
G10	321283	342030	SILVERSTAR
G11	479296	3828890	WYALKATCHEM
G12	334948	3827751	SOKOLL
G13	473245	6056159	MEX94.2.19//SOKOLL/WBLL1
G14	473248	6143869	OAX93.24.35//SOKOLL/WBLL1
G15	473243	6143870	PASTOR//HXL7573/2*BAU/3/MEX94.2.19//ATTILA/3*BCN
G16	472923	6143871	FRTL/SOKOLL
G17	452470	6056135	PASTOR//HXL7573/2*BAU/3/CMH82.575/CMH82.801
G18	460354	6056142	SOKOLL/WBLL1
G19	460356	6056147	PASTOR//HXL7573/2*BAU/3/WBLL1
G20	472927	6056184	MEX94.2.19/PUB94.15.1.12
G21	460334	6056185	W15.92/WBLL1
G22	460360	6056064	PUB94.15.1.12/WBLL1
G23	473269	6056186	PUB94.15.1.12/3/FRTL//ATTILA/3*BCN
G24	472924	6056175	PUB94.15.1.12/FRTL

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stress are presented in Table 2. Analysis of mean yield of both the groups differ significantly. Early maturing genotype (EMG) was found to be the low yield potential crop as compared to the late maturing genotype (LMG). The percentage decrease in the yield of EMG was 17.63% in turn it was found to be 31.67% in LMG that was almost twice of EMG. It may be due to environmental effect on the number of days required for the occurrence of different growth stages of wheat, which also varied with genotypes. The planting wheat at optimum sowing date would realize optimum season length and achieve high grain yield as a result of suitable weather conditions prevailing through different wheat growth stages in both the groups. LMG group genotypes had more yield under timely sown conditions as compared to the EMG under same conditions. But the results were vice versa under late sown more heated environment stress conditions. It may be due to late sown wheat crop, which were generally exposed to high temperature stress during the months of March and April (at anthesis stage), which in turn reduced the yield mainly by shortening the reproductive and ripening growth phases. The response of wheat to both chronic heat stress and short term heat shock is well documented and many of the current wheat grown in the Southern Great Plains region have shown susceptibility in terms of their inability to maintain yield and quality under high temperatures (Yang *et al.*, 2002). Delay of wheat sowing date reduced wheat yield as a result of exposure to high temperature, which reduce season length (Mostafa *et al.*, 2009).

From among the genotypes, EMG had the minimum TOL (33.0) in early group and in LMG group G17 and G24 had a value of TOL 41.9 and 73.1, respectively. Late sown conditions may cause sterility and in turn low yields and more

Table 2. Grain yield in less (Yp) and more heated (Ys) conditions and different stress indices for early and late maturing groups of wheat genotypes

Genotype	Yp	YS	MP	TOL	STI	SSI	GMP	RP	HSI
Early maturing genotype									
G1	508.5	354.4	685.7	154.1	0.743	1.761	424.51	61.52	1.489
G2	516.3	436.8	734.7	79.50	0.930	0.895	474.88	77.13	0.885
G3	513.7	358.9	693.1	154.8	0.760	1.751	429.37	64.81	1.362
G4	492.1	422.1	703.1	70.00	0.857	0.827	455.75	85.77	0.550
G5	545.5	457.8	774.4	87.70	1.030	0.934	499.72	77.00	0.890
G6	531.3	460.6	761.6	70.70	1.010	0.773	494.68	86.69	0.515
G7	546.0	466.8	779.4	79.20	1.052	0.843	504.84	85.49	0.561
G8	523.6	454.6	750.9	69.00	0.982	0.766	487.88	90.64	0.362
G9	536.8	478.4	776.0	58.40	1.059	0.632	506.75	79.10	0.808
G10	424.8	304.8	577.2	120.0	0.534	1.642	359.83	73.302	1.033
G11	446.2	376.8	634.6	69.40	0.693	0.904	410.03	81.189	0.728
G12	345.8	312.8	502.2	33.00	0.446	0.554	328.88	84.09	0.615
Mean	494.22	407.06	697.74	87.15	0.841	1.024	448.10	78.89	0.816
LSD (0.05)	1.31	1.82	2.28	1.74	0.060	.125	1.08	2.56	0.098
CV%	12.1	15.3	12.5	22.7	14.6	22.4	13.2	11.2	21.9
Late maturing genotype									
G13	470.4	388.5	664.6	81.90	0.703	0.544	427.49	82.58	0.674
G14	569.2	359.6	749.0	209.6	0.788	1.150	452.42	68.72	1.210
G15	506.8	383.6	698.6	123.2	0.748	0.759	440.91	75.69	0.941
G16	557.9	337.4	726.6	220.5	0.725	1.235	433.86	60.47	1.530
G17	408.8	366.9	592.2	41.90	0.577	0.320	387.28	97.08	0.112
G18	359.1	241.5	479.8	117.6	0.334	1.023	294.48	67.25	1.267
G19	521.5	373.8	708.4	147.7	0.750	0.885	441.51	71.67	1.096
G20	512.4	363.3	694.0	149.1	0.717	0.909	431.45	70.90	1.126
G21	486.5	208.6	590.8	277.9	0.390	1.785	318.56	42.87	2.211
G22	533.4	288.4	677.6	245.0	0.592	1.435	392.21	54.06	1.778
G23	579.7	349.3	754.3	230.4	0.780	1.242	449.98	51.39	1.882
G24	549.5	476.4	787.7	73.1	1.008	0.415	511.64	90.31	0.374
Mean	504.6	344.77	676.99	159.83	0.676	0.975	415.15	69.42	1.183
LSD (0.05)	1.009	2.431	2.811	1.885	0.052	0.123	1.240	4.583	0.177
CV%	13.0	20.5	12.7	37.4	26.9	34.0	14.4	22.9	32.0

The table is the mean of periodic experiments conducted in the year 2011-12 and 2012-13

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Table 3. Correlation coefficient for grain yield in two different environmental conditions and indices of early maturing group

Yield Indices	Ys	MP	TOL	STI	SSI	GMP	RP	HIS
Yp	0.815***	0.978***	0.244	0.923***	0.025	0.938***	-0.031	0.031
Ys		0.917***	-0.361	0.973***	-0.554	0.965***	0.485*	-0.485
MP			0.038	0.982***	-0.180	0.989***	0.152	-0.151
TOL				-0.143	0.970***	-0.105	-0.864	0.864***
STI					-0.355	0.998***	0.305*	-0.305
SSI						-0.319	-0.864	0.864***
GMP							0.276*	-0.276
RP								-0.999

*, **, *** significant at 0.05, 0.01 and 0.001 probability, level, respectively

TOL value. Singh and Pal (2003) found that the late sowing caused shortening in the total growth duration and significant reduction in the biological and economic yields through reduction in the number of spikes per plant, number of grains per spike and grain dry weight per shoot. This could be attributed to reduction in the rate of leaf appearance as a result of water stress which reduces assimilate production by tillers and consequently reduce wheat grain (Auld and Paulsen; 2003). Yang *et al.* (2002) also reported that grain yield was positively correlated with HSI at 20/15°C. Results indicated that, the G12 and G24 in early and late group, respectively had the lowest SSI among the other genotypes in their respective groups. G24 with high grain yield in optimum and post-anthesis heat stress conditions, had higher STI compared to other genotypes in the late maturing group, but G12 had the lesser value for STI in early maturing group. Thus, the problem with using SSI as a measure of adaptation to stress is that there were cases where SSI has been positively correlated with grain yield reduction in that genotypes whose yield was affected little by the stress also had very low yield potential. This means that the genotypes with low SSI also may have had low stress resistance yield (G12). On the other hand, selecting varieties based on individual index or binary compare of them is tedious, and requires the method that can distinguish the performance of each cultivar in both environments with moderate and severe heat stress in the presence of different indices simultaneously. Analyses of descriptive statistics on grain yield and other yield indices also differ significantly. Therefore, these indices should be considered as produced potential indices and can be used to separate the genotypes with good production and high tolerance towards the stress conditions. In order to study the simultaneous effects on grain yield, correlation matrix characteristics were used. Table 3 and 4 showed the highest variation between data expressed by all the indices. The close positive association (r=.998***) in early group and (r=.996***) in late group also indicated that STI and GMP were more suitable traits for screening the genetic material for heat tolerance under variable stress conditions. These yield indices (STI, MP and GMP) had a high match with yield in both environments and therefore these can be named as a produced potential indices.

It's clear from the proceeding discussion that all stress indices were adversely affected by temperature stress, which were finally reflected in yield reduction. The impact of this adversity could be clearly seen to a large extent in late maturing genotypes, However, there was clear cut variation among the genotypes for late planting conditions. The existing variability in relation to various stress indices had immense importance for selection of parents, which could be

Table 4. Correlation coefficient for grain yield in two different environmental conditions and indices of late maturing group

Yield indices	Ys	MP	TOL	STI	SSI	GMP	RP	HIS
Yp	0.385*	0.925***	0.508**	0.722**	0.278*	0.736**	-0.314	0.315*
Ys		0.707**	-0.598	0.911***	-0.773	0.907***	0.724**	-0.724
MP			0.143	0.929***	-0.104	0.937***	0.056	-0.056
TOL				-0.222	0.964***	-0.206	-0.949	0.949***
STI					-0.447	0.996***	0.392*	-0.392
SSI						-0.439	-0.974	0.974***
GMP							0.384*	-0.380
RP								-0.999

*, ** and ***, significant at 0.05, 0.01 and 0.001 probability levels, respectively

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utilized for improvement of these traits. The measurement of STI, MP and GMP was found to be important because they are closely related to yield production. Their significance becomes crucial particularly under stress environment.

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Land Reforms and Agrarian Relations in The State of Kerala, India- A Socio-Economic Evaluation

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Abstract:: Kerala is one among the few Indian States which took initiation in the area of land reforms in early years. The reforms brought about considerable change in socio-economic status of the local inhabitants. This article attempts to analyze the evolution of various land reforms implemented in the state from 1956 to 2012. This article also seeks to examine the changes in the agricultural scenario in addition to the socio-economic and cultural changes brought by such reforms in the state. Attempts were also carried out to critically evaluate the inadequacies associated with the reforms and scope for its modification.

Key Words: Land Reforms, Agrarian Relations, Socio-Economic Evaluation

Land reforms have been a national agenda of rural reconstruction since independence. They refer to attempts by the Government to achieve social equality and optimum utilization of land by redistributing the land holdings. These reforms are also intended to reorder the agrarian relations in order to achieve a democratic social structure, to eliminate exploitation and social injustice within the agrarian system and thereby enlarging the land base of the rural poor, to provide security for the tiller of the soil and to remove obstacles arising from the agrarian structure that has been inherited from the past and to increase agricultural productivity and infusing an element of equality in local environments. But despite this vision of the Nation, there was inertia, lack of sincerity by governments and pressure tactics of powerful land owning class discouraged land reforms in most of the states. Moreover, land demand for industrial, urban and other complicated economic development issues have resulted in the evacuation of many thousands of marginal farmers and those who were living in agriculture-oriented cottage industries. They were thrown out of their livelihood, drove off their habitats, resulting in their agglomeration in the outskirts of big cities forming slum clusters.

Kerala is one of the few Indian States which implemented land reforms. The present article is an attempt to analyze the effectiveness of such reforms on the socio-economic and cultural aspects of the people of Kerala, right from the origin of State. Attempts were also carried out to critically evaluate the inadequacies associated with the reforms in the contemporary situations and scope for their modification.

Kerala-A Profile: The State of Kerala, stretching for about 590 Kms., with a width varying from 32 to 120 Kms., is a long but narrow strip in the south-west coast of India, sandwiched between towering mountains and the deep blue sea. The networking rivers together with backwaters form an attractive feature of Kerala. The deltas of the rivers interlink the backwater and provide excellent water transport facility in the low lands. The tall, exotic coconut palm dominates the landscape.

The state is divisible into three geographical regions, the highlands, midlands and the low lands (coastal plains). The highlands are dominated by the Sahya Mountains (Western Ghats) with dense tropical evergreen forests, misty peaks, extensive ridges and ravines. Anamudi is the highest peak with an altitude of 2775 m. above MSL. Tea, coffee, rubber, cardamom, cinnamon, oil Seeds and sandalwood are extensively cultivated in the mountainous areas. The midlands have undulating hills and valleys growing coconut, arecanut, banana, mango, tapioca, pepper, ginger etc. The sandy coastal region or the low lands has extensive coconut groves, paddy fields, river deltas, backwaters and the sea. The diversity in geographical set up is reflected in the climate as well. While the highland areas experience biting cold, the climate is pleasant in the midland areas and low land area is comparatively hot because of humidity especially in summer months. South-West monsoon, which is the major monsoon in Kerala begins sometime in June-July and continues till August-September. North-East monsoon commences in October-November.

The state occupies an area of 38,863 Sq.Kms., representing only 1.18 percent of the total area of the country.

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Nevertheless with a total population of more than 30 million people, Kerala has 3.43 percent of the total population of the country.

Landmark Legislations-Land Reforms: The state of Kerala was officially formed in the year 1956. Even before its formation, there had been endeavors at land reforms in the State. The Restriction on Possession and Ownership of Lands Bill (1954) being the best example of the same.

The first democratically elected government assumed office on 5th April, 1957. The first elected government issued the Stay of Eviction Proceedings Ordinance to afford interim protection to tenants, including the 'kudikidappukars' (hutment dwellers). Reports say that close to two million acres were transferred to 1.3 million households. In spite of delays in implementation and circumvention of the legislation, the abolition of tenancy was a remarkable success. The aggregate area transferred to the lessee amounted to 36.5% of the net sown area in the state, or 42.9% of the area excluding plantation crops (Eashvaraiah 1993).This was followed by the agrarian reform bill, which was adopted by the Kerala assembly in June 1959.Its outcome, the Kerala Agricultural Relations Bill (KARB) was a land mark in the history of Kerala. It contained three important features.

(1) No holding of land by permanent tenants, including farm servants and mortgagees, would be subject to resumption by the landowners. The rent to be paid by tenants was reduced to a maximum of one fourth of the gross produce, and to much less, as low as one twelfth, in the case of less fertile land.

(2) All rights of the landlords in land held by the tenants were vested in the state which then would act as an intermediary in transferring (part of) sixteen annual installments of the fair rent to the landowner. After paying all installments, the ex-lessee would receive full ownership of the land. The total abolition of tenancy involved in this arrangement was an exemplary feature of the KARB.

(3) All land above the ceiling limit (15 acres of double cropped land per family, with no additional allowance for adult or minor family members) was to be distributed by the Land lords.

The KARB was a radical departure, not in terms of an anti-capitalist agenda, but in terms of "its democratic revolution which aimed at breaking the backbone of feudalism and semi-feudalism of all kinds, and parasitic landlordism, with a serious concern for development of the forces of production" (Eashvaraiah, 1993).But the implementation of this comprehensive land reform programme was scotched by the overthrow of the first government, the verdict of the Kerala High Court against certain provisions of the bill and the presidential disapproval. The KARB, after the extended legislative procedure, was sent to the President of India on 27 July 1959. Four days later, on July 31, 1959, the government was dismissed by the President, arguing on the basis of Article 356 of the Constitution that law and order in the state had been eroded. This argument was with reference to the prevalence of a violent agitation, the Liberation Movement (Vimochana Samaram).

In February 1960, second ministry assumed power. The Hon. President later sent the KARB back to the Government for modification. The resulting KLR Act of 1964 was a diluted version of the KARB in the sense that it contained more loopholes for ineffective implementation such as the bureaucratic composition of the Land Boards and the exemptions for charitable trusts and plantations. The ideas, which the first government had introduced in 1957, remained intact, and the jenmi landlords in Kerala, and the political parties representing their interests, apparently had changed their tactics. Kerala Land Reforms Act, 1963 is the principal land reform law in the State of Kerala and was included in the Ninth Schedule to the Constitution.

The re-adornment of the first Government for a further term in 1967, allowed for new legislation to undo the evictions (Kerala Stay of Eviction Proceeding Act of 1967), with retrospective effect and to re-modify the KLR Act, resulting in the Kerala Land Reforms (Amendment) Act 1969.This is because in the course of implementation, the State Government had faced serious practical difficulties and to overcome them, that Act was extensively amended by the Kerala Land Reforms (Amendment) Act, 1969 (Act 35 of 1969) and by the Kerala and Reforms (Amendment) Act, 1971 (Act 25 of 1971). Certain crucial provisions of the principal act as amended were challenged in the High Court of Kerala and in the Supreme Court, creating a situation of uncertainty in the effective implementation of land reforms. Although the High Court of Kerala have upheld the scheme of land reforms envisaged in the principal act as amended, a few vital provisions have been struck down. Even in regard to the provisions upheld by the High Court, the affected parties had moved the Supreme Court in appeal. The Supreme Court in its judgments delivered on 26th and 28th April, 1972, have upheld the scheme of land reforms as envisaged in the principal Act as amended, but agreed with the High Court, invalidating certain crucial provisions.

Efficacy of Land Reforms / Evaluation of the Success: The major economic problems of the newly independent nation could be income-poverty, hunger,

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illiteracy, lack of schooling, avoidable disease, and subject to what were among the worst forms of class, caste, and gender oppression in the world.

To solve the agrarian question is to free the countryside of landlordism, old and new; to free the working peasantry and agricultural workers from their present fetters and to guarantee them the means of income and livelihood; to redistribute agricultural land; to provide the rural working people with house-sites and homes; to create the conditions for the liberation of the people of the oppressed castes and tribes and of women; to ensure universal formal education; and to achieve the general democratization of life and progressive cultural development in rural India. Kerala was one of the few states which took brave step of land reforms in early years, where the landless agricultural workers were provided land to settle down. The result was highest public health and distribution of basic educational facilities and least slum dwelling.

The Land Reforms Bill of 1959 introduced by the first ministry had the very clear objective of breaking landlordism. It wanted to realize the slogan of "land to the tiller" which had been the promise of the freedom struggle. The idea was to make tenants the owners of the land they cultivated and to ban future tenancy in all forms. Resuming land for "own-cultivation" which was a euphemism for tenancy-at-will or wage-based cultivation, and which had been the bane of land reforms undertaken by other governments, was not permitted.

But even though the first government could not implement its proposed legislation, the lead it provided started a process that broke to a considerable extent the feudal shackles over Kerala's society and economy. In the assessment of Nossiter (1982), the land reforms program indeed was "the first comprehensive measure of its kind attempted in India; and it tackled tenurial relations of greater complexity than anywhere else in India" (Herring 1983; Radakrishnan 1989). It is also noticed there was no going back on the agenda, the first government had put forth, and in the course of time Kerala emerged as the most successful state in the area of land reforms. But even in the midst of various success stories, it remains as a fact that there are enough of setbacks. One among such is the case of tribal population and fishermen community, two important segments of the poor who could not directly benefit much from the land reforms measures.

Recent Allegations / Proposal for Modification: Nearly 50 years after the first elected government in the state started redistributing land to the poor, politicians and academics are still debating its efficacy. Success stories are many. Some of them states that more than 3.3 million people in the state have benefited from land reforms and today, landless population of the state has been dwindled to only 4.8%. The government has already taken over more than 99,277 acres and redistributed 71,400, and is still to acquire another 43,776 acres. It is also stated that 5.28 lakh persons, mostly agricultural labourers, many of them belonging to the Scheduled Castes, had received allotments of house sites and dwellings. Apart from the direct benefits, the movement for land reforms had led to a series of successful struggles against caste oppression and for mass education, public health and public distribution of food and essential commodities. What is significant about the picture is that while there has been redistribution of power, influence, opportunities and wealth from the highest level of the former agrarian hierarchy, which largely coincided with the highest in the caste structure, to the middle level of both the agrarian and caste-community structure, such redistribution has not happened in the same manner further down.

Some school of thought argues that land reform, implemented in the State was a diluted version of the Bill introduced by the first government in 1959. Those reforms were flawed for the primary reasons that it excluded the estates and plantation sector from the purview of the land ceilings fixed then and it dropped the concrete schemes for reaching land to the real farmers. The Bill had actually set a liberal land ceiling of 15 acres for a five-member family, but even this was scuttled through legal loopholes and benami deals. As a result, the surplus land for redistribution, which was estimated initially as three lakh acres, got reduced to 0.5 lakh acres.

Few political groups have decided to launch agitations for restructuring the land ownership pattern in the State by taking up its earlier slogan `land to the tiller.' Agitations, demanding the continuation of agrarian reforms are also in operation. A call for a second round of land reforms in Kerala has also triggered friction within the government and among various segments of the society. It was pointed out that the reforms in Kerala had several historic achievements to its credit. The process broke the backbone of landlordism and abolished the jenmi system. By 1993 it had conferred ownership rights / protection on 28 lakh tenants, and 6 lakh acres (242812 ha) had been accrued to tenants. Much of the recent criticisms have come from economists who argue the reforms haven't achieved their real purpose as most beneficiaries were not from the lowest rung of society. According to them, an impression of success was created as several intermediate castes and the middle-class are benefited from the reforms. The results of the reforms have been that the tenants (`kudiyans'), who were actually the middle class sections in the State, became the

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owners of the land while the genuine landless farmers and the poor agricultural workers were driven away to settlement colonies. It was also argued that while the middle classes in rural Kerala had gained substantially from land reforms, these had not substantially benefited the landless agricultural labourers, the tribal people or the fisher folk.

As land reforms are considered the one outstanding achievement of the Kerala development experience, the obvious question to ask is why this has not solved the food problem once and for all. Why after 50 years does Kerala depend on Andhra Pradesh for rice, Tamil Nadu for vegetables and Karnataka for meat? Can such a society based on external dependence on food to such an extent be considered a model?

Precisely, land reform did not increase agricultural production or rural employment in the State. In fact, one of the most visible results of the land reform legislation was the extreme fragmentation of land, the oft-cited reason for making agriculture a low-profit venture in the State. Many new landlords realised that they could not make a living out of agriculture and turned to less labour-intensive crops or were forced to seek avenues that could generate additional income. Increasingly, they displayed a tendency to leave their lands fallow. The result was a drastic fall in employment in the agricultural sector also and a rise in farm wages disproportionate to the yield. Workers began to migrate to non-agricultural sectors, especially to satisfy the demand caused by large-scale construction activity. At one point, the Gulf boom pushed up land prices so high that selling agricultural land for real estate development became an enticing option.

Thus it has stated that land has become a mere speculative asset instead of becoming the primary means of production. The tendency to leave the land barren became predominant and consequentially this led to gross decline in the agricultural production, particularly rice. Large-scale concentration of land with the NRIs and the consequent 'absentee-landlordism' has aggravated these trends. Accordingly rice cultivation has been shrunken to about 275,000ha in 2006-07 from more than 800,000ha in the 1960s and production had halved to 630,000 tonnes. The state has already lost about 500000 hectares of paddy fields in the last three decades causing acute food insecurity and severe groundwater shortage. The high costs and lack of farm labour as an indirect result of higher education, have contributed to rice fields being converted for cultivation of other crops or real estate. It is also as a consequence of the simultaneous increase in two categories of people—those who have land but are unable to cultivate and those who have the labour and skills but do not have any or enough land of their own to cultivate. On the current situation in Kerala, the coexistence of high wages in agriculture and high levels of unemployment was noted as an issue that had to be addressed by bringing about cooperation between peasants and agricultural labourers, and promoting investment in agriculture. Another major adverse consequence of the land reforms implemented in Kerala was the emergence of the middle class sections that did not consider land as a primary source of generating livelihood. The middle class had wrested a major clout in the political, economic, bureaucratic and cultural arena of Kerala, and it was their development agenda that was the root of the stagnation of the productive sector and of the degeneration that has gripped the entire gamut of Kerala society. It was also pointed out that periodic change of governments had made it difficult to implement land reforms in a thoroughgoing manner. The major challenge of declining prices of agricultural products in the context of Globalisation and Liberalisation was also a key issue and had to be seen as being as important as the land issue. The problem of management of an open economy like Kerala in the era of globalisation was a task that had to be addressed.

The crisis in Kerala's agricultural sector, which has a large part dominated by cash crops, was complete with the introduction of the liberalisation policies in the 1990s. The price of coconut, a major crop, fell sharply with the reduction of import tariffs on edible oil. The market for rubber, another important crop, was depressed following large-scale import of natural rubber. All plantation crops in which Kerala had a substantial stake, namely, tea, coffee, rubber and cardamom, had also to compete with low-cost imports. The most discernible trend in the past few decades, indeed, has been the marked shift in the cropping pattern towards less labour-intensive crops. In food-deficit Kerala, as stated earlier, the area under paddy fell drastically by over five lakh hectares (from eight lakh hectares) in the past three decades. Although over 60 per cent of the land that went out of paddy cultivation continued to be used for agriculture, the preference was to grow coconut, rubber, areca nut or crops such as banana, tapioca and vegetables. Now, farmers are turning increasingly to quick-profit cultivation of exotic varieties such as vanilla, horticulture and medicinal plants, which have markets outside India.

But, despite the fall in agricultural production and agricultural employment as a result of land reforms, until recently there had been no attempt to undermine the reform measures. For over three decades after the 1970s, farmers and farm workers were, however, living with a new set of problems, of low profits from the fragmented land and lack of employment despite guaranteed minimum wages.

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There is a need to re-look at the reforms and promote agriculture without taking away land rights and legalize collective farming on fallow land. It is still not too late for the Government of Kerala to decree that beneficiaries of the land reforms must transfer the land to the Government if they do not cultivate it. Such lands can be leased out to those many willing to cultivate them. Further, reversal of the, by now, irrelevant anti-tenancy legislation is long overdue. The existing law banning tenancy is fuelled by the dogma that all tenancy is exploitation. It prevents the needed re-allocation of resources and hastens the alienation of agricultural land. The state government, in response, recently legislated the Kerala Conservation of Paddy Land and Wetland Act, which calls for three years imprison and penalty ranging from Rs. 50,000 to Rs1 lakh for those diverting rice land for other uses is a good inititiative in the direction of ensuring food security to the nation.

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Characterization of Farming System in North Gujarat Agro-Climatic Zone

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Farm economic efficiency is an important factor of productivity and growth, where resources are scarce and opportunities for developing and adopting better technologies have lately started declining. Several researchers have suggested farming system as an approach for meeting the multiple objectives of poverty reduction, food security, competitiveness and sustainability (Norman, 1978). The system approach emphasizes the need to view the farm situation as a whole and not in compartmentalized manner. A farming system is the result of complex interactions among a number of interdependent components. To achieve it, a farmer allocates certain quantities and qualities of land, labour, capital and management i.e., the four factors of production to which he has an access. An alternative farming system, which yields not only higher income but also utilizes family labour efficiently, needs to be evolved. Further, the system should help in restoration of ecological balance. The basic aim of integrated/sustainable farming system is to derive a set of resource development, management and utilization practices that lead to a substantial and sustained increase in agricultural production. Since farming systems differ in different situations such studies should be location specific (Singh, 1998). The present study attempts to evaluate the economics and sustainability of different farming systems and to suggest optimum farming system for realizing higher income and ensuring environmental security.

Survey on characterization of farming system was carried out in Mehsana and Banaskantha districts of north Gujarat, which falls under 4.2 Agro-ecological Sub Zone. Using the stratified random sampling technique and following the proportional allocation method. 144 farmers belonging to the size groups, based on the size of operational holding *viz.*, marginal (up to 1 ha), small (1-2 ha), medium (2-4 ha) and large (above 4 ha) were selected from these two districts. The data on socio-economic parameters, existing farming system, economics of different enterprises, farm constraints, etc. were obtained in pre-tested schedules by personally interviewing the selected farmers. The study pertained to the year 2009-10.

The survey revealed that out of 144 farmers, report in Table 1 selected farmers according to their land holding were categorized as marginal farmers (48), small farmers

Table 1. Details information regarding selected farmers of north Gujarat agro-climatic zone (n=144)

Name of district	Name of taluka	Name of village	Categories of farmers				Total farmers
			Marginal	Small	Medium	Large	
Mehsana	Mehsana	Hebuva	4	4	2	2	12
		Piludara	4	4	2	2	12
		Virampura	4	4	2	2	12
	Vijapur	Rampura	4	4	2	2	12
		Dhanpura	4	4	2	2	12
		Madhi	4	4	2	2	12
		Sub total	24	24	12	12	72
Banaskantha	Deesa	Pedal	4	4	2	2	12
		Sherpura	4	4	2	2	12
		Gugal	4	4	2	2	12
	Danta	Aderan	4	4	2	2	12
		Bachadiya	4	4	2	2	12
		Kundel	4	4	2	2	12
		Sub total	24	24	12	12	72
		Grand Total	48	48	24	24	144

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(48), medium farmers (24) and large farmers (24 nos.). The distribution of selected farmers under study engaged in various farming system according to their percentage is depicted in Table 2. It can be seen that 49.31 per cent of the selected farmers were engaged with oilseed farming, followed by 18.06 per cent who were engaged in fruit-vegetable farming system. The lowest number of farmers people were engaged in cereal farming system (2.08 %).

Table 2. Distribution of Farming system in per cent among North Gujarat agro-climatic zone (n=144)

Farming system	Marginal	Small	Medium	Large	Total
Cereal	4.17	0.0	0.0	4.17	2.08
Oilseed	41.67	54.17	58.33	45.83	49.31
Cotton	14.58	16.67	16.67	16.67	15.97
Fruit -veg	22.91	12.50	16.67	20.83	18.06
Spice	4.17	2.08	4.17	4.17	3.47
Livestock	12.50	14.58	4.17	8.33	11.11
Total	100.0	100.0	100.0	100.0	100.0
Sample size	48	48	24	24	144

Table 3. Distribution of farming systems according gross income in north Gujarat agro-climatic zone (n=144)

Farming systems	Source of income							
	PO	LS	CT	CL	SP	VF	Other	Total
Cereal	26.32	21.75	2.72	44.56	0.0	1.90	2.75	100.0
Oilseed	43.77	13.38	14.12	16.16	6.59	4.71	1.27	100.0
Cotton	26.29	13.16	39.16	17.57	1.85	0.26	1.71	100.0
Fruit -veg	15.11	12.24	2.34	16.13	1.13	50.88	2.17	100.0
Spice	17.07	15.57	16.59	9.15	41.62	0.0	0.0	100.0
Livestock	20.57	36.60	7.66	17.44	4.12	9.43	4.18	100.0

Table 4. Predominant Farming systems in North Gujarat Agro climatic zone (n=144)

Farming systems	Marginal	Small	Medium	Large	All
CL+OS+CT	4.17	0.0	0.0	4.17	2.08
Cereal based	4.17	0.0	0.0	4.17	2.08
OS+CL+LS	10.42	18.75	8.33	12.50	13.19
OS+CL+CT+LS	12.50	18.75	16.67	8.33	14.58
OS+CL+SP+LS	0.0	0.0	8.33	8.33	2.78
OS+CL+CT+SP+LS	8.33	10.42	20.83	16.67	12.50
OS+CT+SP+LS	10.42	6.25	4.17	0.0	6.25
Oilseed based	41.67	54.17	58.33	45.83	49.31
CT+CL+OS+LS	14.58	12.50	8.33	12.50	12.50
CT+CL+OS+Fruit	0.0	25.00	8.33	25.00	3.47
Cotton based	14.58	37.50	16.67	37.50	15.97
FT+CL+CT+LS	8.33	0.0	0.0	8.33	4.17
V+CL+OS+LS	10.42	10.42	4.17	8.33	9.03
V+CL+LS	4.17	2.08	4.17	4.17	3.47
V+CL+OS+LS+Tob	0.0	0.0	8.33	0.0	1.39
Fruit -veg based	22.92	12.50	16.67	20.83	18.06
SP+CL+OS+FT+LS	4.17	2.08	4.17	4.17	3.47
Spice based	4.17	2.08	4.17	4.17	3.47
LS+CL+OS+Tob	4.17	6.25	0.0	0.0	3.47
LS+CL+OS	6.25	2.08	0.0	0.0	2.78
LS+CL+OS+Veg	0.0	4.17	4.17	4.17	2.78
LS+CL+OS+CT+SP	2.08	2.08	0.0	4.17	2.08
Livestock based	12.50	14.58	4.17	8.33	11.11
Total	100.0	100.0	100.0	100.0	100.0
Sample size	48	48	24	24	144

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The distribution of selected farmers under study engaged in various farming system according to their gross income is depicted in Table 3. It can be observed that the farmers of cereal farming system are getting highest (44.56%) of gross return from cotton and livestock whereas, lowest (1.90%) gross returns from vegetable-fruit based farming system. Similarly, farmers of oilseed farming system are getting highest returns (43.77 %). The farmers engaged in livestock are getting gross returns 36.60 per cent from livestock followed by oilseed farming system (Table 3).

The predominant cereal, oilseed, cotton, fruit-vegetable, spice and livestock farming systems were recorded in the area (Table 4). The highest per cent of people were engaged in oilseed farming system (49.31 %) whereas, lowest in cereal based farming system (2.08 %).

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Effect of Biomethanated Distillery Spentwash on Growth, Yield and Anatomy of Maize (*Zea mays* L.)

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In India, approximately 40 billion litre of distillery spentwash are being discharged annually from 319 distilleries (Kanimozhi and Vasudevan, 2010). However, its direct use in agricultural field is generally not considered safe because of its high Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Alternatively, the raw spentwash is subjected to biomethanation treatment to decrease BOD and COD and the product is known as Biomethanated Distillery Spentwash (BDS). The agricultural use and the beneficial effect of spentwash have been well documented by many authors. The main problem with the distillery effluent is potassium and chloride ion concentration. The K that enters the xylem stream may enter through many putative uptake pathways. Some of those pathways have been identified through molecular and the electrophysiological level, but the identity of the primary K^+ uptake pathway is still not clear. BDS is rich in K ion might have altered the respiration and it may change the anatomy of roots. The work on BDS effect on anatomical study is quite limited. The present work is focused on the study of growth, yield and anatomy of maize due to BDS application and also determination of the adaption level in the field.

The BDS was collected from the distillery unit of M/S. Bannari Amman Sugars Ltd., Periyapuliyur, Erode, Tamil Nadu and analyzed for its physico-chemical properties by following standard procedures (APHA, 1998). BDS was dark brown colour and a neutral pH (7.42) with high EC (32.5 dS m^{-1}), BOD (6,545 mg L^{-1}) and COD (34,476 mg L^{-1}). It contained highest K (8,376 mg L^{-1}), N (2,116 mg L^{-1}), Ca (2,072 mg L^{-1}), Mg (1,284 mg L^{-1}) and P (52.8 mg L^{-1}). Field experiment was conducted during August to December, 2009 at Research and Development farm of M/S. Bannari Amman Sugars Distillery Division Ltd., Erode. Different doses of BDS along with inorganic fertilizers using maize hybrid COH (M) 5 as test crop have been tried. The experiment was laid out in Randomized Block Design with seven treatments and three replications (Table 1). Spentwash was applied as per the treatment and incorporated into the soil at 30 days before sowing in order to reduce the BOD and COD load. Seed rate was 18 kg ha^{-1} with the spacing of 60 x 25 cm and the plots were irrigated immediately after sowing. Recommended dose of nitrogen @ 150 kg ha^{-1}, phosphorus @ 75 kg ha^{-1} and potassium @ 75 kg ha^{-1} were applied. Fifty per cent of N and full doses of phosphorus and potassium were applied as basal and the remaining half dose of N was top-dressed after 30 days of sowing. Biometric observations were made by randomly selecting five plants in the net plot area of individual treatments at four stages *viz.*, vegetative (30 DAS), flowering (60 DAS), maturity (90 DAS) and harvest (120 DAS). The leaf area index was calculated by the method as suggested by Williams (1946). Crop growth rate was estimated by the method suggested by Watson (1958). The cobs from the net plot were harvested separately and expressed in kg ha^{-1} and yield attributes *viz.*, cob length, cob weight $plant^{-1}$ and number of grains cob^{-1} were recorded. Anatomical changes of root tissues were compared with control and spentwash applied treatments by using rotary microtome as suggested by Allen and Sanders (1997).

Effect of BDS on Growth Parameters: Application of BDS significantly influenced the growth parameters compared to control. Among the different stages, harvest stage (120 DAS) recorded the highest plant height and stem girth (Table 1) and the highest leaf area index was recorded at 60 DAS . Among the various doses, BDS @ 100 kilo litre ha^{-1} + RD of NPK registered the highest plant height, stem girth, leaf area index and crop growth rate. The spentwash contained various cations and anions, which promotes the plant growth by increasing water absorption and other metabolic processes of plants. The highest growth attributes might be due to the addition of increased plant nutrients to the maize crop through the distillery spentwash. Better utilization of available resources might have increased the functional leaves and in turn enhanced the LAI (Sivasankari, 2009). Significant difference in crop growth rate was observed from 30 to 60 DAS onwards. The increased in CGR due to BDS might be attributed to be increased LAI. Enhanced effect of

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BDS on CGR might be due to higher accumulation of photosynthates in the sink which lead to higher CGR.

Effect of BDS on Quality Parameters: The highest total chlorophyll content and soluble protein was recorded in BDS @ 100 kilo litre ha^{-1} + RD of NPK and the lowest in control. An increase in chlorophyll content was recorded in leaves of maize at all the BDS concentration on 60 and 90 DAS and subsequently decreased due to the onset of senescence (Table 2). This reflects the high manurial potential of the distillery effluent. The increased soluble protein might be due to cells retained higher water potential with the application of spentwash. This might have prevented protein degradation metabolism and enhanced soluble protein synthesis by activating enzyme activity (Nandakumar, 2009).

Effect of BDS on Yield and Yield Attributes: BDS application caused a significant increase in yield attributes. Among the treatments, BDS @ 100 kilo litre ha^{-1} + RD of NPK recorded the highest cob length , cob weight, number of grains per cob and grain yield which was on par with BDS @ 100 kilo litre ha^{-1} + RD of NP (Table 3). The reason was due to be the BDS is essentially a plant extract, the increased nutrient supply and coupled with good soil fertility status and improved physical properties, which were made available to the plants, thus resulting in better growth, development and yield attributes of the maize (Madhumitadas *et al.*, 2010).

Effect of BDS on Anatomy: The anatomical structure in the cross-section of the root and the possible modification of the root tissues were corresponded with the changes due to the BDS application. The cross section of the control roots showed a normal cellular composition with no aerenchymatous tissue and the spentwash applied roots of maize showed many aerenchymatous cells in the parenchyma and it was not uniformly distributed (Fig. 1). The aerenchyma cells in the roots are an adaptation of plant to overcome certain stresses, which commonly affect the oxygen supply to root for respiration. The results from present study revealed that the application of BDS @ 100 kilo litre ha^{-1} + Recommended dose of NPK increased the growth and physiological parameters and these are highly correlated

Table 1. Effect of BDS on plant height, stem girth, leaf area index and crop growth rate at varies stages of maize

Treatment*	Plant height (cm)				Stem girth (cm)				Leaf Area Index				Crop growth rate x ($g\ m^{-1}\ day^{-1}$)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	65.1	213	230	233	1.45	4.22	6.82	7.03	0.42	1.48	1.07	0.74	3.45	5.37	24.3	7.46
T_2	69.4	228	254	256	1.87	4.85	7.24	7.46	0.66	1.76	1.32	0.97	3.87	5.48	25.8	7.85
T_3	70.4	232	256	260	2.06	5.17	7.53	7.72	0.75	2.04	1.58	1.11	4.04	5.64	25.9	8.56
T_4	77.2	246	269	272	2.69	5.84	8.14	8.27	1.13	2.47	2.06	1.54	4.89	6.02	28.2	9.24
T_5	80.2	252	276	279	2.78	5.95	8.38	8.54	1.27	2.67	2.24	1.82	5.12	6.34	29.6	9.95
T_6	71.8	239	260	263	2.25	5.36	7.72	7.93	0.94	2.13	1.75	1.28	4.15	5.89	26.0	8.87
T_7	73.5	242	265	268	2.34	5.68	7.86	8.02	1.08	2.35	1.89	1.35	4.36	5.97	26.7	9.13
CD 5%	3.61	11.8	12.9	13.6	0.11	0.25	0.37	0.44	0.04	0.12	0.09	0.07	0.29	0.47	2.28	0.92

*T_1: RDF; T_2: BDS @ 50 kilo l ha^{-1} + NP; T_3: BDS @ 50 kilo l ha^{-1} + NPK; T_4: BDS @ 100 kilo l ha^{-1} + NP; T_5: BDS @ 100 kilo l ha^{-1} + NPK; T_6: BDS @ 150 kilo l ha^{-1} + NP; T_7: BDS @ 150 kilo l ha^{-1} + NPK

Table 2. Effect of BDS on total chlorophyll and soluble protein at varies stages of maize

Treatment*	Total chlorophyll ($mg\ g^{-1}$)				Soluble protein ($mg\ g^{-1}$)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
T_1	2.45	2.52	2.67	2.51	1.45	4.22	6.82	6.49
T_2	2.56	2.63	2.79	2.67	1.87	4.85	7.24	6.78
T_3	2.58	2.67	2.82	2.72	2.06	5.17	7.53	7.05
T_4	2.74	2.91	3.01	2.92	2.54	5.74	8.14	7.59
T_5	2.85	3.02	3.13	2.99	2.78	5.95	8.38	7.87
T_6	2.63	2.72	2.88	2.77	2.25	5.36	7.72	7.18
T_7	2.69	2.84	2.99	2.87	2.34	5.68	7.86	7.39
CD (p=0.05)	0.09	0.09	0.10	0.09	0.07	0.14	0.18	0.15

*As in Table 1

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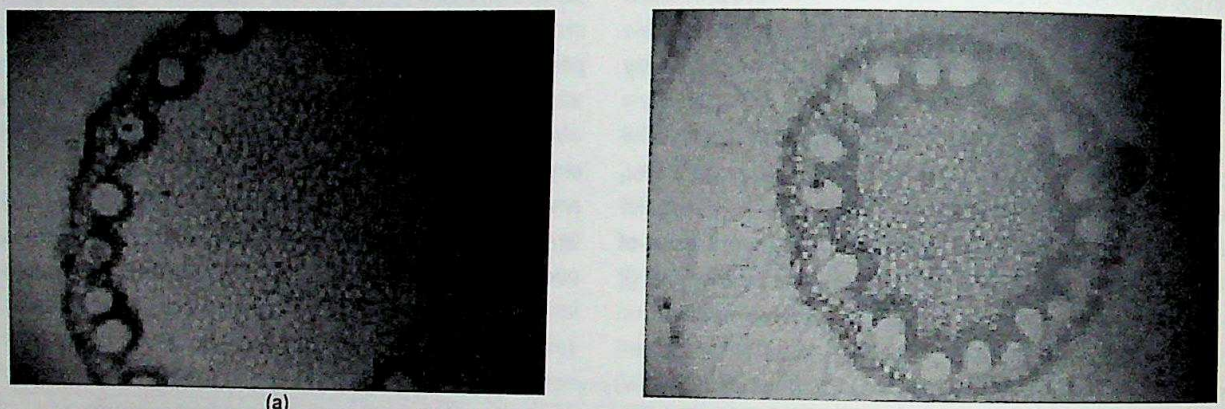
Table 3. Effect of BDS on yield attributes and grain yield of maize

Treatment*	Cob length(cm)	Cob weight plant^{-1}(g)	No. of grains cob^{-1}	Grain yield (kg ha^{-1})
T_1	14.52	158.4	516.5	3917
T_2	15.48	170.5	538.6	4265
T_3	16.26	192.4	543.8	4493
T_4	21.42	260.3	576.3	5759
T_5	23.84	278.7	581.8	5815
T_6	17.75	220.5	544.6	5543
T_7	18.63	228.5	558.4	5670
CD (p=0.05)	0.88	10.12	21.06	87.90

*As in Table 1



(a) (b)

Fig.1. Transverse section of maize root grown with normal (a) and effluent (b) water irrigation under the high resolution fluorescent microscope

with yield of maize crop. Hence, distillery spentwash from sugar mills hitherto considered as factory waste could be used as a source of nutrients to maize.

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Influence of Land Use Pattern on the Nitrate Contamination of Groundwater in Coimbatore District, Tamil Nadu

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Nitrate contamination in groundwater is a common problem in any part of the world arising from diffuse reasons, e.g. intensive agriculture, unsewered sanitation in densely populated areas, or from point sources such as irrigation of land by sewage effluents. Nevertheless, the heavy use of nitrogenous fertilizers in cropping system is the largest contributor to anthropogenic nitrogen in groundwater worldwide. Nitrogenous fertilizer rapidly converts into NO_3^- form in soils, which is readily available to plants, but is highly soluble and hence easily leachable to deep soil layers and ultimately accumulates into the groundwater (Kundu *et al.*, 2008). Elevated concentrations of nitrate in drinking water can cause low oxygen levels in the blood of infants, known as methemoglobinemia or blue baby syndrome, a potentially fatal condition (Wolfe and Patz, 2002), and have been associated with the occurrence of cancer in adults through the formation of carcinogenic N-nitroso compounds (Weyer *et al.*, 2001) and to non-Hodgkin's lymphoma (Ward *et al.*, 1996). As such, the US Environmental Protection Agency (US EPA) has established a maximum contaminant level of 10 mg/l NO_3-N (US EPA, 2000).

Nitrate occurs naturally in groundwater. However, septic leakage, dairy and poultry farmings, nitrogen fertilizers and animal manures applied to soil can cause elevated levels of nitrate in groundwater (Babiker *et al.*, 2004). Many research projects have examined the relationship between specific land use patterns, corresponding pollutant emissions and the resulting groundwater quality (Lerner and Harris, 2009; Chen *et al.*, 2010). High groundwater nitrate has been positively correlated with surrounding agricultural land use (Lockhart *et al.*, 2013). Thus, the objective of this present investigation was to study the influence of different land use pattern (crop field area, habitation area and dairy / poultry farming areas) on nitrate contamination of groundwater.

Water samples were collected from different sources *viz.*, open well, bore well and hand pump located in crop field area (346 samples), habitation area (109 samples) and dairy / poultry farming areas (22 samples), at different villages spread over in the 18 blocks of the Coimbatore district of Tamil Nadu during the month of January, 2008. Due to the industrial influences, the samples were not collected from two blocks *viz.*, Palladam and Tirupur. Sampling was done at a spatial distance of approximately 2 to 3 km away from each other areas. While sampling from agricultural fields, care was taken to select the sites having almost similar type of cropping systems over a large area around them for ascribing any possible effects of cropping system on the loading of NO_3-N in the aquifers beneath.

The pH and EC values of the water samples were measured *in-situ* immediately after collection by using portable pH meter and conductivity meter. The NO_3-N content was measured by forming a purple azo-dye out of a coupling reaction between a diazo compound of sulphanilamide and N- (1-napthyl)-ethylene diamine dihydrochloride and recording the colour intensity at 540 nm with the help of a Flow Injection Autoanalyzer (FIASTAR 5000, FOSS Analytical AB, Sweden) with a detection limit of 0.01 µg mL^{-1} NO_3-N following the method described by US EPA (1979). Means of three replicates, range and standard deviation were calculated for all the parameters analysed.

There were little variations in pH and EC values of the groundwater samples. On average, they were neutral to slightly alkaline in reaction and non saline to slightly saline in nature. The NO_3-N content in the sample, however, varied significantly (0.00 to 37.2 mg L^{-1}) in different land uses of the district (Table 1). The mean NO_3-N content was the highest in the water samples collected from dairy/poultry farming areas (9.72 mg L^{-1}) followed by habitation/community areas (6.80 mg L^{-1}) and the lowest in crop field areas (5.93 mg L^{-1}). The formation of nitrate out of ammonia in the dairy farming areas and in the sewage effluents of the habitation areas is higher which may subsequently transported in to the subsoil and then to groundwater for contamination. It might be the reason for higher NO_3-N concentration in the groundwater of dairy farming and habitation areas.

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Table 1. Variations in pH, EC and NO_3-N content of water samples collected from different land use pattern

Land use	Number of samples	pH	EC (dS m^{-1})	NO_3-N (mg L^{-1})
		Mean±SD	Mean±SD	Mean±SD
Crop field area	346	8.18±0.45 (7.11-9.16)	1.67±1.40 (0.03-8.63	5.93±5.49 (0.00-26.5)
Habitation/ Community area	109	8.20±0.48 (7.07-9.13)	1.72±1.46 (0.06-9.31)	6.80±6.28 (0.00-35.4)
Dairy/Poultry farming area	22	8.14±0.41 (7.48-9.06)	1.97±1.37 (0.32-5.42)	9.72±8.40 (0.08-37.2)
Total	477	8.18±0.45 (7.07-9.16)	1.70±1.41 (0.03-9.31)	6.31±5.89 (0.00-37.2)

Figures in parenthesis are range values

Out of 477 samples analyzed, 14.7, 38.2 and 27.5 % water samples contained 0-1, 1-5 and 5-10 mg L^{-1} NO_3-N content respectively. Whereas 19.7 % samples recorded NO_3-N content more than 10 mg L^{-1}. Groundwater contamination of NO_3-N was more in dairy/poultry farming areas followed by habitation/community areas and less in crop field areas. About 40.9 % samples collected from the dairy/poultry farming areas contained NO_3-N more than 10 mg L^{-1} compared to only 17.3 % of the samples from the crop field areas.

Among the predominant cropping systems, the mean NO_3-N content in the samples was highest (7.56 mg L^{-1}) in the areas were the vegetables –pulses cropping system was followed and it was followed by turmeric-pulses > millets–pulses > banana-ratoon banana/vegetables > coconut > sugarcane – ratoon sugarcane > cotton-millets/pulses > rice–rice/pulses (Table 2). Ju *et al.* (2007) reported that under shallow rooted heavily fertilized vegetable crops, nitrate losses as a result of leaching could be very large. The crops which have deep and wide rooting pattern can absorb more NO_3-N from the soil profile thus minimizing its percolation to the groundwater. Similar findings were reported by Babiker *et al.* (2004). The lower concentration of NO_3-N in the rice-rice cropping system might be due to an increased loss of nitrate through denitrification under the anaerobic condition existing in the rice-rice system. Andrade and Stigter (2009) stated that in low land rice fields with fine textured soils, leaching loss of nitrogen are low because of restricted percolation.

Results indicated that inspite of intensive cultivation with heavy fertilization, the water samples collected from dairy/poultry farming areas and habitation/community areas were highly polluted compared to crop field areas. Nitrate-N build up in groundwater is possible, where shallow rooted crops such as vegetable crops and turmeric are grown with high nitrogenous fertilizers.

Table 2. NO_3-N content in groundwater under different cropping system

Cropping System	Mean Nitrate-N content (mg L^{-1})
Millets-Pulses	6.53
Vegetables –Pulses	7.56
Coconut	5.25
Cotton-Millets/Pulses	5.13
Banana-Ratoon banana/Vegetables	6.23
Turmeric-Pulses	6.95
Rice-Rice/Pulses	3.64
Sugarcane – Ratoon sugarcane	5.19

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Competitiveness of Wheat (*Triticum aestivum* L.) Cultivars under Spacing and Weed Levels

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The yield of wheat crop is controlled by a number of genetic and external factors. An optimum level of single factor will not cause any appreciable increase in the yield itself, but a combination of factors contributes to the yield of wheat. It is well recognized that by keeping proper row spacing and inputs like varieties, fertilizers and seed rate etc. have an effective role in increasing the yield of crops (Bakht *et al.*, 2007; Kour *et al.*, 2011 and Sekhon *et al.*, 2012). It is well documented that infestation of weeds cause substantial yield losses in various crops, accounting for 45 per cent yield losses in wheat (Kler *et al.*, 2002). It is imperative to control the weeds to increase the grain yield of wheat. For smothering weeds, it is desirable to optimize crop competitiveness, which depends upon genotypic characters of the varieties and also proper spacing etc. Competitive cultivars may therefore be an important component of integrated weed management strategies (Mahajan *et al.*, 2013). In modern cropping systems, herbicide application is the most effective weed management. However, the increasing use of herbicides leads to herbicide resistance in weeds and enhancement of environmental and human health risks. Therefore, reducing herbicide application is one of the most important approaches. In the absence of herbicides, weeds are controlled through agronomic practices, including crop rotations, cover crops, intercropping, tillage (Barberi, 2002) and improvement of crop competitiveness (Rezvani *et al.*, 2013). Some crop traits such as tillering, height (Lemerle *et al.*, 2001) canopy diameter, leaf area and partitioning of leaf area and dry matter (Rezvani *et al.*, 2010) can play effective role in increasing competitiveness. In Punjab, several commercial wheat cultivars are adopted by farmers, with little information on their performance in weedy condition. This study evaluated the competitiveness of three wheat cultivars against weed flora and to find out the suitable spacing for effective weed management.

The experiment was conducted on wheat at Students' Agriculture Farm, Khalsa College, Amritsar, situated at 31° 38' North latitude, 74° 52' East longitude and at an attitude of 236 metres above mean sea level during *rabi* season. The treatments comprised of three cultivars of wheat (PBW 621, PBW 550 and PBW 343), three spacing (15 cm, 20 cm and bidirectional 22.5 x 22.5 cm) and two weed levels (weed free and unweeded check) in Factorial RBD with 3 replications. The soil of the experimental field was loamy sand with pH 7.5, low in organic carbon 0.35. Sowing of the crop was done manually with single row hand driven drill on 12 November 2011. For variety PBW 343 and PBW 621, seed rate of 100 kg ha^{-1} was used, whereas for PBW 550, 112.5 kg ha^{-1} seed was used. Seed was treated with Chloropyriphos 20 EC (4 ml kg^{-1}) and Vitavax (2 g kg^{-1}) and RDF was applied at the time of sowing and N (urea) was applied in two splits after sowing. Cultural practices followed were in accordance with the recommendations of PAU Ludhiana. Plant height (cm), number of grains per ear, thousand grains weight (g), straw yield (kg ha^{-1}), grain yield (kg ha^{-1}), weed count and weed dry weight were recorded for evaluation.

Plant Height: The maximum plant height was attained by the variety of PBW 621, which was statistically at par that plant height of PBW 343. It was significantly better than the of PBW 550. It shows that PBW 621 and PBW 343 being tall cultivars have a competitive advantage over cultivar of PBW 550. The bi-directional sowing at 22.5 cm x 22.5 cm and closer spacing of 15 cm attained significantly better plant height than sowing at 20 cm. Similar results were also reported by Bakht *et al.* (2007). They reported that plant height varied due to varieties. In weed free plots, plants attained significantly better height than plants of unweeded check plots.

Weed Count: Cultivars PBW 621 and PBW 343 had 34.77 and 27.79 per cent less weed count, respectively than PBW 550. The difference in the ability of cultivars PBW 621 and PBW 343 to suppress weed growth more than PBW 550 might be due to taller plants (Dhima et al., 2008) and more tillers. Presence of these attributes in cultivars of PBW 621 and PBW 343 conferred better competitiveness against most

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Table 1. Effect of different treatments on yield and yield attributing characters of wheat, weed count and weed dry matter accumulation.

Treatment	Plant height (cm)	Effective tillers (per sq m)	1000-grain weight (g)	Ear length (cm)	Grains per ear	Straw yield (q ha^{-1})	Grain yield (q ha^{-1})	Weed count (per sq m)	Weed dry weight (q ha^{-1})
Cultivars									
PBW 621	99.5	383.5	39.1	11.0	46.2	84.09	58.55	7.9 (109.9)	3.3(15.7)
PBW 550	86.8	336.5	39.6	10.2	40.5	75.25	52.39	9.1 (148.2)	3.8(21.2)
PBW 343	95.9	369.0	37.0	10.1	39.9	75.01	52.22	8.1 (115.9)	3.4(16.6)
CD (5%)	5.8	34.2	2.1	0.6	1.9	6.73	4.69	0.4	0.2
Spacing									
15 cm	96.8	372.6	39.1	10.6	43.2	80.51	56.05	8.0 (112.0)	3.6(16.0)
20 cm	87.0	328.3	37.0	10.0	38.5	71.74	49.94	9.3 (153.3)	3.8(21.9)
Bi-directional (22.5 x 22.5 cm)	98.4	388.1	39.6	10.8	44.8	82.10	57.18	7.9 (108.7)	3.3(15.6)
CD (5%)	5.8	34.2	2.1	0.6	1.9	6.73	4.69	0.4	0.2
Weed Treatment									
Weed free	97.1	388.7	40.0	11.3	44.4	82.88	57.71	1.0 (.0)	1.0(.0)
Unweeded check	91.1	337.3	37.1	9.6	40.0	73.35	51.07	15.7 (249.4)	6.0(35.6)
CD (0.05)	4.7	27.9	1.72	0.47	1.53	5.49	3.83	0.3	0.1

Figures in the parentheses are the means of original values before the transformation (square root transformation) of data.

weeds than cultivar PBW 550 with shorter plants and less tillers. Bidirectional sowing (22.5 cm x 22.5 cm) and closer spacing of 15 cm reduced the weed count by 41.0 per cent and 36.9 per cent, respectively in comparison with spacing of 20 cm. Crop sown with bidirectional method and closer spacing of 15 cm provided the more competition to weeds for space, moisture, nutrients and light, which resulted in less weed population.

Weed Dry Weight: Data recorded on weed dry weight on statistical analysis revealed that cultivar PBW 621 had a competitive advantage over weeds as it recorded minimum weed dry weight, which was followed by cultivar PBW 343 and maximum weed dry weight was observed in cultivar PBW 550. It could be due to the less population of weeds, which resulted in less weed dry weight. Bidirectional sowing (22.5cm x 22.5cm) and closer spacing 15 cm also reduced the weed dry matter accumulation by 15.66 and 5.49 per cent, respectively in comparison with normal spacing 20 cm (Table 1).

Grain and Straw Yield: Cultivar of PBW 621 was superior to the other two varieties in terms of grain yield. Cultivar of PBW 621 gave significantly more grain yield i.e., 11.75 and 12.12 per cent than cultivars of PBW 550 and PBW 343, respectively. The differences among the varieties in grain and straw yields might be due to the genetical differences among cultivars and different genotypes concerning dry matter partitioning where wheat cultivars might differ in carbon equivalent, yield energy per plant (Abd El-Gawal *et al.*, 1987). Bidirectional sowing of crop at 22.5x22.5 cm and unidirectional sowing at 15 cm gave 12.66 and 10.9 per cent more grain yield, which was significantly better than grain yield obtained from unidirectional spacing with 20 cm. These results are in conformity with the findings of Fonts *et al.* (1997) who reported that grain yield decreased with increase in spacing. Also, the unweeded check resulted in significant reduction of yield as compared to weed free treatment. Cultivar of PBW 621 was superior to the other two varieties in terms of straw yield and gave significantly higher straw yield (11.75 and 12.10%) than cultivars of PBW 550 and PBW 343. In case of spacing, significantly higher straw yield was found under bidirectional sowing at 22.5 cm 22.5 cm as well as in closer spacing of 15 cm than in spacing of 20 cm. Weed free treatment recorded significantly higher straw yield in comparison to unweeded check treatment.

Wheat cultivars had the differential weed suppression ability due to the variation in yield, growth and yield contributing characters. Cultivar of PBW 621 proved highly competitive genotype against weeds, which had higher plant height, effective tillers that led to more yield contributing characters. Bidirectional (22.5 x22.5 cm) and closer spacing (15 cm) sown wheat showed significant smothering effect on weeds and produced significantly higher yield than spacing of 20 cm. It also showed that crop should be weed free for higher yield.

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Biology of Sugarcane Aphid (*Ceratovacuna lanigera* Zehntner) upon Selected Sugarcane Host Plants

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Sugarcane (*Saccharum officinarum*) is the most important economic crop of the tropical area and contributes nearly 70 per cent of the world's total sugar production. Besides, it is also a source of fuel, food and fodder. The sugar industry is the second largest agro-based industry in India with 64.6 tone/acre and 10.36 per cent sugar recovery. The crop is attacked by about 288 species of insect and non-insect pests based on their damage causing 20 per cent in cane yield and 15 per cent in sugar recovery. The sugarcane woolly aphid (SWA), *Ceratovacuna lanigera* Zehntner (Homoptera: Aphididae) has become a threat to the sugarcane crop as well as sugar industry (Patil and Nerker, 2004)

There is lack of research about biology of sugarcane woolly aphid related to varietal resistance plant belonging to Bixaceae and Combretaceae. Patil *et al.*(2004) studied the colonization of *C. lanigera* on sugarcane varieties and found that the released aphids could not colonize on resistant clones even after 2nd to 3rd days of release, whereas on susceptible genotypes including commercial varieties, aphids immediately colonized within 42 hours, after infestation, indicating the possibility of antibiosis and /or non-performance mechanisms in suppressing the pest and arresting further colonization and spread. Also, Wensler and Fishie (1969) reported that aphids have a more intimate relationship with their host plants than many other pests and are affected by small changes in the nitrogen status of the host. The present study was conducted to evaluate relationship between sugarcane aphid and six selected genotypes with the special reference to biology and distribution of pest in sugarcane fields.

The four selected genotypes were planted by taking each genotype in a row of six meter length under the greenhouse condition with a spacing of 40 cm x 10 cm between rows and plants, respectively with four replications. For studying the biology of apterous/alate form of sugarcane aphid, single apterous/alate adults were confined on the lower surface of leaf with the help of perforated OHP sheet cage. Thereafter, daily observations were recorded to study the duration of each nymphal period, total nymphal period, fecundity and longevity.

Freshly laid first apterous nymphs were yellowish green in colour without any woolly matter on their body. The nymphal duration was shortest (2.25 days) on CoC 671, while it was longest (3.00 days) on Co 91010 (Table 1). The second apterous instar nymphs were yellow in colour without woolly coat on the tested varieties; the nymphal duration varied from 3 to 5 days. The nymphal duration was again shortest (3.25±0.5 days) on Co C 671 and it was longest (4.50 days) on Co 91010, whereas similar nymphal duration was recorded on other varieties of sugarcane.

The third apterous instar nymphs were yellowish brown in colour with whitish waxy filaments all over their bodies. The duration of the nymphs ranged from 6 to 11 days among different varieties. The shortest nymphal period of 7.50±1.29 days was observed on CoC671, being at par with Co 99004 (7.75±1.50days), Co2001-09 (8.50 days) and Co 91010 (8.75±1.26 days). The duration of the third instar nymph was longest on Co 79158 (10.00±1.15 days) and being at par with Co 2001-09 (8.50±1.91 days).

The body of the fourth instar nymph apterous was covered with white matter and the nymphal duration ranged from 7 to 11 days among the different varieties. The duration of the subsequent instar nymphs remained same on all the varieties tested as they were statistically at par with each other.The moulted aphids in all the instars were bright yellow in colour and easily distinguishable.

The total nymphal period varied from 18 to 27 days among the different varieties. The nymphs duration varied from 21.50 to 24.50 in CoC 671 and Co 91010 days. The adult apterous aphids had woolly matter covering their body on dorsal remaining same on all the varieties which ranged from 9-16 days as they were on par with each other. The apterous aphids were parthenogenetic, but viviparous type of

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reproduction was also observed and the adult aphid gave birth to first instar nymphs among the different varieties. Significantly highest (84.00±14.99 nymphs/adult) fecundity was recorded on CoC 671, which was at par with Co 2001-09 (83.25±7.63 nymphs/adult) and it was lowest (50.00±13.83 nymphs/adult) on Co 91010, being at par with Co 79158 (55.50±14-71 nymphs/adult). The total nymphal period was shortest in highly susceptible variety CoC 671 (21.50 days), whereas it was longest in moderately resistant variety Co 91010 (25.75 days). Adult longevity remained same in different genotypes as they were statistically on par with each other. Fecundity was comparatively higher in susceptible varieties than highly resistant varieties via Co 91010 and Co 79158.

The present finding revealed that there was five days difference in the total nymphal duration of CoC 671 and Co 79158 that may be due to antibiosis mechanism operating in the variety and it helps to reduce the number of generations/year. Several studies carried out on the biology of apterous SWA, but there is no literature to discuss its biology in resistant and susceptible sugarcane varieties to evaluate the antibiosis mechanism of resistance.

Puttanwar (2004) reported the mean duration of first, second, third and fourth instar SWA as 2.43, 4.21, 7.31 and 8.06 days, respectively and mean total nymphal period as 23.01 days. Takano (1941) from Japan reported that the nymphal period lasted from 23-33 days. Chang *et al.* (2000) from Taiwan reported adult longevity of 20-24 days and Shankar and Shitole (2004) mentioned that nymphal period lasted for 20 days. These results are more or less similar with the present study which supports rearing of SWA on different genotypes. Puttanawar (2004) reported the mean longevity of SWA as 15.90 days and is consistent with the present study. The fecundity of SWA on different varieties in the present study is similar with the result of Puttanawar (2004) who reported it as 46.51 nymphs/ female and Chang *et al.* (2000) reported 41.0-56.6 nymphs/adult in the lifetime which agrees with the present study. But, it was contradictory with Patil and Nerker (2004) who reported 21.7 young ones in the life span of the female.

The biology of alate SWA was studied under greenhouse condition from March 2012 to July 2012 in four different sugarcane varieties and the results are presented in Table 2. Freshly laid first instar nymphs were blackish to olive green in colour without woolly matter on their body. After 1-2 days, thin layer of woolly matter development was seen around their body. First instar nymphs duration remained same which ranged from 2 to 4 days on different varieties being at par with each other. Similarly, the second instar (3-5 days), third instar (10-12 days) and fourth instar (9-11 days) nymphal duration were also remained same on all the varieties under test. Second instar nymphs were greenish yellow in colour, where as third and fourth instar nymphs were yellowish brown in colour with whitish waxy filaments on their body. The total nymphal period remained same on all the varieties as they were at par with each other and it varied from 24 to 30 days among the different varieties. Also, adult longevity remained same on all the varieties which ranged from 6 to 12 days as they were at par with each other. The adult alates were parthenogenetic but viviparous type of reproduction was observed in sugarcane woolly aphid and adult aphid gave birth to first instar nymphs directly. The fecundity ranged from 12-33 aphids/adult among the different varieties. Significant highest (19.50 nymphs/adult) fecundity was recorded on CoC 671 which was at par with all the varieties except co 79158 (13.50 nymphs/adult). The mean duration of alate SWA in different instars ranged from 3.25, 3.75, 4.25, 4.75, 10.50, 11.25 and 9.25-10.00 days in first, second, third and fourth instars respectively in different sugarcane genotypes with no significant difference. The total nymphal period and adult longevity remained same in all the evaluated genotypes, as they were statistically on par with each other. Highest fecundity was observed in CoC 671(19.50 nymphs/female) and it was longest in Co 79158 (13.50 nymphs/female) as indicated in figure 2.

Based on the present study, it is clear that no

Table 1. Biology of sugarcane woolly aphid (apterous) on four different sugarcane genotypes (Mar- July 2012)

Varieties	Life Stage Duration (days)						
	Instar I	Instar II	Instar III	Instar IV	Total N. P.	Adult	Fecundity (nymphal adult)
	Mean ±SD (Range)	Mean ±SD (Range)	Mean ± SD (Range)	Mean ±SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
CO 91010	3.00 ± 0.72 ab (2 – 4)	4.50±0.58 ab (4 – 5)	8.75±1.50 ab (7 – 10)	8.25±1.50 (7 – 10)	24.57±1.91 abc (22 -26)	13.75±1.89 (11 – 15)	50.0±13.83 b(33 – 64)
CO 79158	2.75±0.50 ab(2 – 3)	3.75 ±0.96 ab (3 – 5)	10.0±1.15a (9 – 11)	9.25 ±1.26 (8 – 11)	25.75 ± 1.71 ab (24 – 28)	13.00 ±1.41 (11 – 14)	55.5 ±14.71 b (38 – 70)
CO 2001-09	2.75 ± 0.50 ab (2 – 3)	3.75 ±0.50 bc (3 – 4)	8.50 ± 1.91 ab (7 - 11)	9.00 ±1.63 (7 – 11)	24 ± 3.83 abc(19 – 27)	13.25 ±2.03 (11 – 16)	83.25±7.63 a (74 - 90)
COC 671	2.25 ± 0.50 (2 – 3)	3.25 ±0.50 c(3 – 4)	7.50 ±1.29 b (6 – 9)	6.50 ±1.29 (7 – 10)	21.50±2.05 c(18 – 24)	12.75 ±2.75 (10 – 16)	84 ± 14.99 a (83 – 97)

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Table 2. Biology of sugarcane wooly aphid on four different sugarcane genotypes (Mar -July 2012)

Varieties	Life stage duration in days (Mean±SD)						
	Instar I	Instar II	Instar III	Instar IV	Total N.P.	Adult	Fecundity (nymphs/adult)
CO 91010	3.50 ±0.58 (3 – 4)	4.75±0.50 (4 – 5)	10.50±1.00 (10 – 12)	9.50±0.58 (9 – 10)	28.25±0.96 (27 – 29)	9.00±2.58 (6 – 12)	17.50±4.95 (12 – 33)
CO 79158	3.25 ±0.50 (3 – 4)	4.50±0.58 (4 – 5)	11.00±0.82 (10 – 12)	10.00±0.82 (9 – 11)	28.75±0.50 (28 – 29)	9.50±0.58 (9 – 10)	13.50±1.29 (12 – 15)
CO 2001-09	3.25 ±0.50 (3 – 4)	4.25±0.50 (4 – 5)	10.50±0.58 (10 – 11)	9.50 ± 1.00 (9 – 11)	27.50±1.29 (26 – 29)	9.00±1.41 (7 – 10)	18.50±1.73 (17 – 21)
COC 671	3.25 ±0.96 (2 – 4)	4.25±0.96 (3 – 5)	10.75±0.50 (10 – 11)	9.25 ± 0.50 (9 – 10)	27.50±2.38 (24 – 29)	9.25±0.50 (9 – 11)	19.50±5.07 (12 – 23)

Figures in parentheses indicate the range

antibiosis operated in resistant varieties against SWA. There is no available literature to justify the result thought many studies have been carried out on the biology of alate SWA. Puttanawar(2004) reported 7.52 days of alate longevity with a fecundity of 15.33 nymphs/female is in agreement with present findings. Singh *et* al. (2004) observed antibiosis on sorghum varieties IS12609L, IS 12664C and TMK428 against sugarcane aphid (*Melanaphissachari*) and reported least number of days to reproduction, greater mortality, shorter longevity and fecundity of fewer nymphs.

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Biology of *Tetranychus ludeni* Zacher (Acari: Tetranychidae) on Brinjal

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Many phytophagus mites have attained pest status causing considerable losses to cultivated crops, particularly vegetables. Phytophagus mites feed on the plants and cause injury. *Tetranychus ludeni* Zacher (Acari: Tetranychidae) is one of the most serous mite pest of vegetable in India (Singh, 1995).The spider mite species, *T. ludeni* is a serious pest of a wide variety of economically important plants. The mite often infests the upper surface of the leaves cause yellowing of leaves, followed by formation of necrotic patches and drying up. It is one of the important mite pests of vegetable crops in India reported to attack French bean, brinjal, potato, watermelon and many other vegetable and fruit crops limiting the production of these crops (Jeppson *et al.*, 1975; Puttaswamy and ChannaBasavanna, 1980b). As a highly polyphagus mite, *T. ludeni* occurs in the field almost throughout the year. Moreover, this is the only spider mite in India known to be a vector of the plant viral disease, *viz.* Dolichos enation mosaic virus (DEMV) (Rajagopalan, 1974). The high intensity of *T. ludeni* infestation on brinjal and the extensive degree of visible damage caused due to the mite attack led to the selection of this plant for the study. The present study gives an account of the developmental strategies of *T. ludeni* infesting *Solanum melongena.*

Culture of *T. ludeni* was raised in the laboratory of Department of Entomology, T. D. Collage Jaunpur by bringing *T. ludeni* infested brinjal and releasing them on leaf disc on wet cotton swab kept in petri dishes. The cotton swab was kept moist so that the leaf containing mites remained green. The leaf discs were changed once in 3-4 days. The mites multiplied rapidly and thus, a fairly pure laboratory culture was obtained. Several such petri dishes were maintained in the laboratory and kept in room temperature. Biology of the mite was studied on leaf discs on wet cotton swab and maintained in the same manner as stated above. Female deutonymph and adult male were released on leaf disc in a series of petri dishes. As soon as the female emerged out of deutonymph, the male mated with female and fertilized female, thus obtained, was allowed to lay eggs. The eggs, obtained on the next day, were observed until they hatched and thus, incubation period was recorded. Subsequent observations regarding duration of different stages were recorded at six hourly intervals. Fecundity of a single fertilized female was observed by isolating an adult female to separate leaf disc as soon as it was fertilized by males just after the emergence of the female. In case of unfertilized female, the deutonymph quiescent stage was transferred to a separate leaf disc. From the same set of experiment, longevity of adult female was recorded. The longevity of a male was obtained by isolating a male at deutonymph stage and transferring it to a separate leaf disc. The observations were made under the stereoscopic binocular microscope..

Adult females exhibited a general preference to the upper surface of leaves though no specific selection of site for depositing of eggs was noticed. Ovipositing females constructed silken web prior to the deposition of the eggs. Eggs were laid single on the under surface of the leaf, preferably along the thick veins under the webbing. The fertilized female produced both males and females.

The incubation period was 4.60 ± 0.89 and 5.00 ± 0.70 days at average temperature of 31.3°C and 37.3°C, respectively. The larval stage was completed in 1.90 ± 0.50, 1.30 ± 0.44 and 1.76 ± 0.53 day at an average temperature of 31.3°C relative humidity 75.0 per cent, and 1.90 ± 0.65, 1.90 ± 0.41 and 1.30 ± 0.27 days at 37.3°C, relative humidity 54.0 per cent (Table 1 and 2). The time required to complete the life cycle was 9.60 ± 1.15 and 10.16 ± 0.42 days at average temperature of 37.3°C and 31.3°C, respectively. The adult male remained for 5.40 ± 0.65 and 5.60 ± 0.92 days while as the adult female lived for 9.45 ± 0.70 and 9.60 ± 0.96 days at above mentioned temperatures, respectively. Average fecundity was 116.6 ± 8.08 and 119.4 ± 6.42 for fertilized female and 57.4 ± 5.85 and 59.2 ± 4.76 for unfertilized female on under similar conditions (Table 1).

The effect of temperature and relative humidity on the development and oviposition was studied by Puttaswamy and ChannaBasavanna (1980a), Gotoh et *al.* (2003) and Haque *et al.* (2007). Among the five temperature (20 ± 1°C,

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Table 1. Duration (in days) of different stages and fecundity of *Tetranychus ludeni* (Mean±SD)

Period	Incubation period	Larva	Protonymph	Deutonymph	Total period Egg to adult	Longevity Male	Longevity Female	Average fecundity Fertilized ♀	Average fecundity Unfertilized ♀
April 2012	5.00±0.70	1.90±0.54	1.30±0.44	1.76±0.53	10.16±0.42	5.60±0.92	9.45±0.70	116.60±8.08	57.40±5.85
May 2012	4.60±0.89	1.90±0.65	1.90±0.41	1.30±0.27	9.60±1.15	5.40±0.65	9.60±0.96	119.40±6.42	59.20±4.76

24 ± 1 °C, 27 ± 1 °C, 30 ± 1 °C and 32 ± 1°C) and five relative humidity (55 ± 3%, 65 ± 3%, 75 ± 3%, 85 + 3% and 95 ± 3 %), the optimum condition for development and maximum survival of eggs were found between 32 ± 1 °C and 35 ± 1°C and 65 ± 3% and 75 ± 3% relative humidity. The optimum condition for development of immature were 30 ± 1 °C to 35 ± 1°C. The lowest numbers of eggs were laid at 20 ± 1°C. High humidity (95 ± 3% R.H.) reduced egg production capacity of adults irrespective of temperature ranges. In their another study by Puttaswamy and ChannaBasavanna (1980), it was found that females took 12.48 ± 0.16 days and males took 11.96 ± 0.38 days to complete the life cycle. Mated and unmated female had oviposition period of 1.54 ± 0.30 days and 1.43 ± 0.11 days, respectively and laid on an average 165.88 ± 47.04 eggs and 132.00 ± 28.54 eggs during their ovipositional periods of 22.83 ± 4.56 days and 27.98 ± 4.50 days and 32.14 ± 4.08 days, respectively. In the present findings, incubation period, larval, protonyphal and deutonymphal period of *T. ludeni* being 5.00 ± 0.70 days and 4.60 ± 0.86 days, 1.90 ± 0.54 days and 1.90 ± 0.65 days; 1.30 ± 0.44 days, 1.90 ± 0.41 days; 1.76 ± 0.53 days and 1.30 ± 0.27 days, respectively. The time taken to complete the life cycle of *T. ludeni* was found to be 10.16 ± 0.42 days and 9.60 ± 1.15 days at relative humidity 75 and 54 per cent and average temperature 31.3 °C and 37.3°C. Its life history has been studied by Mallik and ChannaBasavanna (1983), Nandagopal and Gedia (1995), Haque *et al.* (2007). According to the latter report, the life cycle (egg-adult) took an average of 14.3 days during January. The duration of other stages are; egg (5-8 days), protonymph (3-4 days), deutonymph (3-5 days) and longevity of adult male is 1-4 days whereas female survive from 4-14 days. Sangeeta and Ramani (2007) obtained almost similar result.

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Eco-Friendly Management of Fruit Flies, *Bactrocera* spp. in Guava with Methyl Eugenol Traps in Punjab

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Guava is an important fruit crop of Punjab occupying 8.07 thousand hectares. However, fruit flies, *Bactrocera* spp. are the major limiting factors in successful cultivation causing almost 100 per cent damage to rainy season guava crop (Singh and Sharma, 2013) as it is the most preferred host of fruit flies. The fruit flies are very difficult to manage as they are polyphagous, multivoltine, adults have high mobility and fecundity and all the developmental stages are unexposed. Only adults are exposed while eggs and maggots remain protected in the host tissues and most of insecticidal treatments are ineffective. Application of insecticides disrupts the ecosystem and causes numerous hazards, which in the present scenario warrants the need of integrated approach for fruit fly management (Verghese *et al.*, 2012). The use of methyl eugenol traps stands as the most outstanding alternative among the various alternate strategies available for the management of fruit flies. Methyl eugenol, when used together with an insecticide impregnated into a suitable substrate, forms the basis of male annihilation technique (MAT). Thus, keeping in view the importance of fruit flies on guava crop, a technology was devised for management of male fruit flies with methyl eugenol based mineral water bottle traps designated as PAU Fruit Fly Traps.

The trials were conducted in guava orchards for the management of fruit flies by using methyl eugenol based MAT (PAU Fruit Fly Traps) during 2013-14 at 13 locations in 10 districts of Punjab. One litre capacity mineral water bottle trap was used (Plate-1). The trap consisted of a plywood dispenser suspended vertically inside the bottle, aligning with the four vents that allowed entry of fruit flies inside the bottle. The traps used in MAT technique consisted of immersing water absorbable plywood blocks of size 7.5 cm x 6.0 cm x 2.0 cm in a solution of ethyl alcohol, methyl eugenol and malathion mixed in a glass jar in the ratio of 6:4:1 (v/v) for 72 hrs so that this solution could be properly absorbed in the plywood blocks (Singh and Sharma, 2013). For hanging on tree, a hole in the plywood block was made to put wire. Four holes were made on the upper side of the bottle for entry of fruit flies. Bottles were cut from bottom and plywood block was hanged inside the bottle with two sides of wire coming out from the top of the bottle.

Four random holes of 3-4 mm diameter were made at the bottom to drain the rain water. The wire was twisted to make a loop. Sixteen traps/acre were fixed in each guava orchard alongwith an untreated control of one acre area. The baited bottles were hanged with the trees at equidistance. The traps were fixed in the first week of the July till end-October when the fruit harvesting was over.

The height of trap was 1-1.5 metre from ground level at a place receiving no direct sunlight. The lower cut portion of the bottle (lid) was removed and all the fruit flies trapped in the bottle were collected after every 7 days. The fruit flies trapped/trap were counted in the laboratory at weekly interval when the number was low (< 100) but when the large was large enough, the count was made on weight basis. From both the treatments (16 traps/per acre and control), a sample of 50 fruits at random/treatment collected at weekly interval were sorted out as infested (based on the oviposition punctures), maggots emerging out of fruits, fallen

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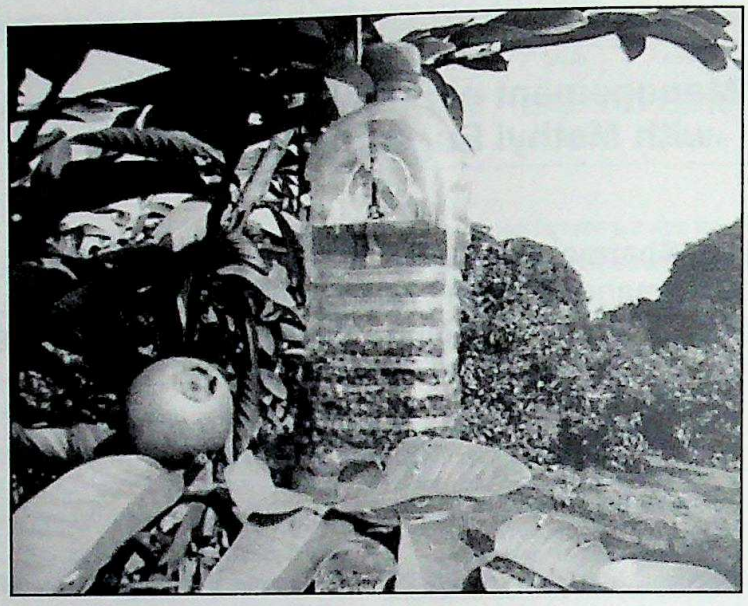

Plate 1. PAU fruit fly trap

fruits and healthy fruits. Impact of traps on the number of marketable fruits was also assessed by counting number of marketable fruits from five trees.

Consolidated data revealed that a total number of 2,51,621 male fruit flies were trapped at 13 locations in 10 districts. In orchards with 16 traps/acre, fruit fly infested fruits were 37.0 per cent as compared to 82.3 per cent in untreated orchards (Table 1). The marketable fruits/tree were 581 fruits/tree in orchards where 16 traps/acre were fixed as compared to 224 fruits/tree in untreated orchards. The data on the male fruit fly catch at different locations indicated that the highest fruit flies/16 traps were at Bahadurgarh (1,20,311 flies) followed by at Ballowal (41,668 flies) whereas minimum flies trapped were at Faridkot (1098 flies). The results further showed that the maximum infested fruits were observed at Jalandhar (57.2 %) followed by 48 per cent each at Pathankot and Ballowal, in 16 traps/acre. In untreated orchard, maximum infested fruits were recorded in Jalandhar (100%) followed by 95 per cent each at Ludhiana-1 and Patiala. The highest number of marketable fruits/tree was recorded at Bathinda (950 fruits/tree), in 16 traps/acre whereas in untreated orchards, maximum number of marketable fruits were recorded at Pathankot (628 fruits/tree).

Jalaluddin *et al.* (2001) assessed the population fluctuations of the *Bactrocera correcta* (Bezzi) in guava orchards using methyl eugenol traps and recorded a distinct population peak from July to August, which coincided with the ripening. Singh *et al.* (2011) recorded number of adult male fruit flies captured/trap at weekly interval in pear in Punjab. Trap catch ranged from 74.9 to 326.4 flies/trap/week during different years.

According to Singh and Sharma (2012), 16 traps/acre fixed in peach orchards at Ludhiana had significantly more population of male fruit flies compared to 4, 8 and 12 traps/acre. More the number of males captured, less was the number of maggots/fruit in the field and 16 traps/acre had significantly less number of maggots/fruit as also observed in the present study. It was further observed that number of traps had a significant impact on the quality marketable fruits and yield. Palam Trap, a lure based mineral water bottle trap was found effective in monitoring and management of 10 species of fruit flies including *B. dorsalis* (Hendel) and *B. zonata* (Saunders) in fruits and vegetables in Himachal Pradesh (Mehta *et al.* 2010) and 16 traps/acre in the present studies with methyl eugenol also attracted both the species. The results on capture of male fruit flies in the present study are comparable with Sharma (2012) who also found that methyl eugenol traps were effective against *Bactrocera* complex on mango, guava, sapota and peach.

This technique has been successfully used for the eradication and control of several *Bactrocera* species (Stonehouse *et al.*, 2007, Vargas *et al.*, 2010). The present findings showed a significant impact in reducing the damage and increasing the number of quality fruits as also reported in earlier studies (Singh and Sharma, 2013). The findings also indicated that 16 traps/acre in guava were very effective in reducing fruit fly damage as also reported by Viraktamath and Ravikumar (2006) in India. It is concluded that successful eco-friendly management of fruit flies in guava can be achieved by fixing PAU fruit fly traps @ 16 traps/acre in the

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Table 1. *Efficacy of PAU fruit fly traps in guava in Punjab*

Treatment	Locations													
	LDH 1	LDH 2	FKA	HSX	PTA	PTK	JUC	BDG	FDK	ASR	BLW	JLW	BTI	Grand total /mean
						Total fruit flies captured/16 traps								
	12,025	10,728	1529	6775	17,836	17,986	2541	1,20,311	1098	NR	41,668	15,744	3380	2,51,621
						Mean per cent infested fruits								
16 traps/acre	30	35	45	12	33	48	57.2	45.4	33	20	48	14	6.6	37.0
Control	95	90	90	78	95	55.2	100	65.8	57.2	90	76	85	92.3	82.3
						Number of marketable fruits/tree								
16 traps/acre	430	365	298	640	801	676	664	193	611	NR	SP	762	950	581
Control	65	58	49	65	295	628	437	86	408	NR	SP	80	300	224

LDH-1 & LDH-2 - Ludhiana, FKA-Fazilka, HSX-Hoshiarpur, PTA-Patiala, PTK-Pathankot, JUC-Jalandhar, BDG- Bahadurgarh, FDK-Faridkot, ASR-Amritsar, BLW-Ballowal, JLW-Jallowal, BTI-Bathinda; NR-Not recorded: SP-Small plants (yield not worth recordable)

first week of July to get higher number of marketable fruits.

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Varietal Preference of Aphid, *Myzus persicae* (Sulz.) on Cumin

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Cumin, *Cuminum cyminum* Linn. is an important spice crop, cultivated in North India. Cumin seeds contain 2-5 per cent volatile oil, which consists of 25-35 per cent aldehydes, pinene and alphaterpineol. The seeds also contain flavonoids (including apigenin). Cumin is extensively cultivated in irrigated sandy loam to loamy soils of South-Western and North-Eastern regions of Rajasthan during *Rabi* season. The cumin aphid, *Myzus persicae* (Sulz.) was reported as the major insect pest of cumin in Rajasthan. This pest was observed causing serious damage at flowering stage of the crop and decreased the crop yield. With the view to provide a sound base to the IPM strategy against a pest, it is essential to study the varietal preference of aphid to generate the useful information on host plant resistance.

The cumin varieties, *viz.,* RZ-19, RZ-209, RZ-223, UC-336, UC-267, UC-293 and UC-339 and local were screened for their resistance against aphid. The crop was sown in a simple randomized block design (RBD) with three replications. The populations of nymphs and adult aphids were *recorded* on five plants per replication at weekly intervals starting from third week of January (initiation of aphid population). The plant height, number of umbels plant^{-1}, days to 50 per cent flowering, days to maturity of each genotype was also recorded. The mean aphid population of cumin varieties recorded during the crop season was categorized on the basis of formula, X ± (Where, X = Mean of peak aphid population, = Standard deviation of peak aphid population). Accordingly, the varieties were categorized as least susceptible (X -), moderately susceptible (X - to X +) as highly susceptible (above X +).

Population of aphid: The aphid population started to build up from second week of January (8 January, 2012) on all genotypes and ranged from 8.23 to 28.35 aphids/three umbels. The minimum population was recorded on RZ-223 which was significant at par with RZ-209 and RZ-19, these genotypes were found significantly superior over other genotypes. More or less similar trend was observed on 15th, 22nd and 29th January, 2012. The aphid population reached to peak in 5th observation recorded on 5th February, 2012. The population was found to be in the range of 101.84 to 130.47 aphids/ three umbels, the minimum being on RZ-223 and maximum on local genotype. The genotype RZ-223 was at par with RZ-209 with respect to aphid population. The maximum population on local genotype was non significant with UC-339 and UC-267.

The population was in declining trend after 5th February, 2014. On 11th March, 2012 the aphid population was very low on all the genotypes and ranged from 10.65 to 48.05 aphids per three umbels. Based on overall mean population of the season, the increasing trend of aphid numbers was observed in the order of RZ-223, RZ-209, RZ-19, UC-293, UC-336, UC-267, UC-339 and local.

Based on the statistical categorization (X ± σ), the mean aphid population was found to be below 63.29 per three umbels and the two genotypes, RZ-223 and RZ-209 were categorized least susceptible to *M. persicae.* The population of aphid was in the range of 63.29- 86.29 per three umbels on genotypes, UC-293, UC-267, UC-336, and RZ-19, therefore, categorized as moderately susceptible. The population of aphid was above 86.29 per three umbels in genotypes UC-339 and local, and categorized as highly susceptible. The results are in full conformity to Kumawat *et al.* (2007), who reported RZ-19, RZ-223 and RZ-209 as least susceptible. The findings also got support from the findings of Meena (1993) who reported RZ-19 as moderately susceptible.

Morphological characters of different genotypes of cumin: The plant height and number of primary branches/plant ranged from 27.96 to 33.02 cm and 4.05 to 6.02, respectively, which showed significant negative correlation with population of aphid. The number of umbels plant^{-1} ranged from 21.82 to 30.37, which had significant negative correlation (r= -0.70) with aphid population (Table 2). The days to 50 per cent flowering influenced the aphid population as these revealed significant correlations (r= 0.80). However, the seed yield was drastically influenced by the aphid population as it ranged from 3.05 to 4.25 q ha^{-1} in different genotypes. The minimum being on local and maximum on RZ-209. Further the seed yield revealed a negative but significant correlation with aphid population (r= -0.76).

The present studies revealed that RZ-223 and RZ-

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Table 1. *Mean population of aphid, Myzus persicae* (Sulz.) on different genotypes of cumin during *rabi* 2011-12

Genotypes	Weekly mean aphid population / three umbels										
	08/01/12	15/01/12	22/01/12	29/01/12	05/02/12	12/02/12	19/02/12	26/02/12	04/03/12	11/03/12	Mean
RZ-19	16.23	70.62	92.25	105.65	120.84	92.74	69.12	51.02	28.72	12.65	66.08
	(1.21)	(1.85)	(1.96)	(2.02)	(2.08)	(1.97)	(1.84)	(1.71)	(1.46)	(1.10)	(1.82)
RZ-209	10.30	67.62	85.96	98.96	105.55	88.68	70.55	55.34	30.00	12.96	62.64
	(1.01)	(1.83)	(1.93)	(2.00)	(2.02)	(1.95)	(1.85)	(1.74)	(1.48)	(1.11)	(1.80)
RZ-223	8.23	65.62	87.25	95.65	101.84	91.74	67.12	50.02	26.72	10.65	60.28
	(.91)	(1.82)	(1.94)	(1.98)	(2.01)	(1.96)	(1.83)	(1.70)	(1.43)	(1.03)	(1.78)
UC-336	20.56	76.52	96.95	101.05	106.08	97.82	85.69	78.49	55.83	31.53	75.09
	(1.31)	(1.88)	(1.99)	(2.01)	(2.03)	(1.99)	(1.93)	(1.89)	(1.75)	(1.50)	(1.88)
UC-267	22.54	82.03	100.92	108.65	119.05	107.01	93.45	85.34	67.92	40.06	82.69
	(1.35)	(1.91)	(2.00)	(2.04)	(2.08)	(2.03)	(1.97)	(1.93)	(1.83)	(1.60)	(1.92)
UC-293	21.44	78.76	94.09	100.11	108.62	104.64	88.36	73.36	48.43	28.04	74.58
	(1.33)	(1.90)	(1.97)	(2.00)	(2.04)	(2.02)	(1.95)	(1.87)	(1.69)	(1.45)	(1.87)
UC-339	25.30	85.35	103.33	112.41	122.93	111.90	99.65	88.74	74.22	45.04	86.88
	(1.40)	(1.93)	(2.01)	(2.05)	(2.09)	(2.05)	(2.00)	(1.95)	(1.87)	(1.65)	(1.94)
Local	28.35	90.06	110.64	118.99	130.47	115.43	102.75	94.00	72.15	48.05	91.08
	(1.44)	(1.95)	(2.04)	(2.07)	(2.12)	(2.06)	(2.01)	(1.97)	(1.86)	(1.68)	(1.96)
C.D. at 5%	0.04	0.05	0.06	0.06	0.08	0.06	0.06	0.05	0.05	0.05	0.07

Figures in the parentheses are log X value

Table 2. Morphological characters of different genotypes of cumin and their relationship with population of aphid, *Myzus persicae* (Sulz.)

Genotypes	Mean aphid population three umbel^{-1}	Plant height (cm)	No. of primary branches plant^{-1}	No. of umbels plant^{-1}	Days to 50% flowering	Seed yield (q *ha*$^{-1}$)
RZ-19	66.08	33.02	6.02	30.37	52.33	3.91
RZ-209	62.64	31.55	5.64	28.13	55.00	4.25
RZ-223	60.28	32.47	5.12	29.87	58.00	4.14
UC-336	75.09	29.35	4.84	22.72	55.67	3.32
UC-267	82.69	30.02	5.11	24.87	63.00	4.02
UC-293	74.58	28.24	4.05	26.43	56.33	3.85
UC-339	86.88	27.96	4.43	27.37	60.67	3.5
Local	91.08	28.28	4.50	21.82	59.00	3.05
Correlation coefficient with mean aphid population (r)		-0.81*	-0.73*	-0.70*	0.80*	-0.76*

* Significant at 5 per cent level

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209 were least susceptible and UC-339 and local genotypes highly susceptible to aphids. The moderately susceptible genotypes were RZ-19, UC-267, UC-336 and UC-293 were the moderately susceptible genotypes. The seed yield was significantlynegatively correlated with aphid population.

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Tritrophic Interaction among Manure Schedule, Fertilizers, Varieties and Incidence of Pests in Cowpea *Vigna unguiculata* (L.)

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Cowpea [*Vigna unguiculata* (L.) Walp] is an important grain legume of the tropics and fodder crop of India. It is an inexpensive source of dietary protein, and a hardy crop well adapted to relatively dry environments (Hafiz and Damarany, 2006). The crop is also important in soil fertility improvement and is reported to fix nitrogen. A well-nourished crop boosts the inherent capacity of the variety to tolerate insect incidence (Alghali, 1992). In this paper emphasis has been given to highlight the influence of fertilizers/ biofertilizer/organic manure on insect resistance and other growth and yield components in three selected cowpea accessions. To evaluate the influence of fertilizer/ biofertilizer/organic manure and resistance of the three selected cowpea accessions CO4, CO6 and P-152 against aphids (*Aphis craccivora* Koch), thrips *Megalurothrips sjostedti* (Trybom) and pod borer (*Lampides boeticus* Linnaeus), a field trial was conducted at the Experimental farm, Department of Agronomy, Annamalai University, Annamalai Nagar with six treatments including control (Table 1).

The field trial was laid out in randomized block design with three replications adopting a plot size of 18 × 9 m and a spacing of 45 × 30 cm between plants. Organic manure, biofertilizer (Rhizobium) and fertilizers (N, P and K) were applied alone or in combination in different blocks. No insecticidal application was given during the entire crop period. Incidence of *A. craccivora*, *M. sjostedti* and *L. boeticus* were recorded from 30 days after sowing (DAS) at seven days interval till the harvest of the crop. The observations were recorded from five plants selected at random in each accession at weekly intervals. The population of *A. craccivora* and *M. sjostedti* was recorded on three leaves from each plant viz., one top, middle and bottom leaf each respectively. The population of *L. boeticus* larvae was recorded on whole plant basis.

The results revealed that the effect of application of different fertilizers, biofertilizers and organic manures alone or in combination showed that least population of aphids was in T_6 (OM+R+NPK). This may be due to the combination of N P and K with biofertilizer and organic manure. The aphid population and thrips population did not vary significantly among different accession. Among the treatments, (OM + R + NPK) and the control treatment recorded the maximum thrips population, whereas it was minimum in rhizobium treated plots. The selected cowpea accessions differed significantly with regard to *L. boeticus* larval population. The accession CO4 recorded minimum *L. boeticus* larval population and the treatment T_5 (R+NPK) recorded the minimum number of *L. boeticus* larvae (0.55) whereas accession P-152 recorded maximum *L. boeticus* larval population.

The application of fertilizers alone or in combination with rhizobium and organic manure leads to the reduction in pod damage by *L. boeticus* larvae. Among the treatments T6 (OM+R+NPK) showed least population damage by *L. boeticus* larvae. The present results are in agreement with the findings of Umaru *et al.* (2002) on maize and Cowpea. The percent pod damage was also negatively correlated with plant height (-0.93), number of pods per plant (-0.93), hundred seed weight (-0.95) and seed yield/plant (-0.94). The present paper revealed that the accession CO6 and P-152 can be well advocated as insect tolerant accessions with higher yield potential tolerant (Table 2).

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Table 1. Interaction of fertilizers, organic manures and biofertilizers with selected cowpea accessions on the Incidence of *A. craccivora*, *M. sjostedti* and *L. boeticus*

Treatments	Population/plant in accessions									Per cent Pod damage by *L.boeticus*					
	A. craccivora			*M. sjostedti*			*L. boeticus*								
	CO4	CO6	P-152	Mean	CO4	CO6	P-152	Mean	CO4	CO6	P-152	Mean	CO4	CO6	P-152	Mean
Control	9.13	10.86	9.00	9.66	1.53	1.60	1.33	1.48	1.20	1.60	1.53	1.44	47.02	43.22	34.68	41.64
Organic manure (OM)	7.46	6.86	5.46	6.60	0.53	0.46	1.13	0.71	1.13	0.53	1.06	0.91	31.43	30.76	29.22	30.47
Rhizobium (R)	4.3	4.46	4.26	4.35	0.40	0.26	1.00	0.55	0.46	0.53	0.73	0.57	26.70	26.20	24.68	25.86
NPK	5.60	4.66	8.00	6.08	1.13	0.93	0.73	0.93	1.00	1.20	1.46	1.22	24.80	23.83	21.19	23.27
OM + NPK	7.93	5.80	6.60	6.77	0.93	0.66	0.46	0.68	0.40	0.66	1.20	0.75	21.47	20.70	19.96	20.71
R + NPK	5.06	6.53	6.33	5.97	1.06	1.26	0.46	0.93	0.60	0.60	0.46	0.55	16.10	14.88	13.10	14.69
OM + R + NPK	3.20	5.53	3.60	4.11	1.06	1.26	2.13	1.48	0.80	1.80	1.33	1.31	15.29	14.65	12.28	14.07
Mean	6.10	6.39	6.18		0.95	0.92	1.03		0.80	0.99	1.11		26.12	24.89	22.16	
	$CD_{(p=0.05)}$															
Among accessions	NS				NS				0.23				0.40			
Among treatments	1.72				0.46				0.36				0.61			
Accessions x Treatments	2.97				0.86				0.63				1.06			

Table 2. Correlation between percent pod damage and growth characters and yield components of cowpea

		X_1	X_2	X_3	X_4	X_5	X_6
Percent pod damage	X_1	1.0000					
Plant height	X_2	-0.9005	1.0000				
Number of seeds per pod	X_3	-0.9374	0.9783	1.0000			
Number of pods per plant	X_4	-0.9309	0.9590	0.9950	1.0000		
Hundred seed wt. (g)	X_5	-0.9521	0.9747	0.9957	0.9933	1.0000	
Seed yield plant (g)	X_6	-0.9491	0.9735	0.9974	0.9962	0.9993	1.0000

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Tomato Leaf Curl Virus Incidence and Association Studies in Tomato

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Tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetable in India. Efforts are being made to increase its productivity by developing superior varieties. Yield, being a complex quantitative character, it depends on a number of contributing traits. Therefore, the knowledge of association of different components together with their relative proportion indicates only the interrelationships of the characters but does not furnish information on cause and effects. So to increase plant productivity, consideration should be given to susceptibility to tomato leaf curl virus disease (Kaur *et al.*, 2012). Therefore, the present study was undertaken to get the information on resistance to TLCV disease in tomato genotypes, which ultimately helps in developing the superior varieties.

Thirteen genotypes, which included 10 progenies of cross M-3-1 × H-36 along with two parents and check Dhanashree were sown in randomized block design (RBD) with three replication at MPKV, Rahuri during autumn-summer season 2010-11. Transplanting was done at a spacing of 90 × 30 cm in a plot size of 3.60 × 3.0 m^2. All the recommended cultivation practices were followed to raise a good crop. Observations were recorded on five randomly tagged competitive plants from each genotype for yield and yield contributing characters. Twelve important productivity traits, *viz.*, days to initiation of flowering, days to 50% flowering, days to first harvest, harvesting duration, number of harvestings, number of fruits per plant average fruit weight, fruit length, fruit width, pericarp thickness, total soluble solids (TSS) and fruit yield per plant were studied to find out genotypic and phenotypic correlation coefficients. The per cent disease incidence and coefficient of infection was calculated as per the procedure recommended by Banerjee and Kalloo (1987).

Estimates of genotypic and phenotypic correlation coefficient (Table 1) revealed that the genotypic correlation was in higher magnitude than the corresponding phenotypic

Table 1. Estimates of genotypic (G) and phenotypic (P) correlations coefficient for different characters in tomato

Character	r	1	2	3	4	5	6	7	8	9	10	11	12
Days to initiation of flowering	G	1.00	1.00**	1.00**	-0.50**	-0.47**	-0.37*	-0.59**	-0.62**	-0.53**	-0.19	-0.55**	-0.84**
	P	1.00	0.83**	0.55**	-0.34*	-0.34*	-0.25	-0.40*	-0.28	-0.31	0.16	-0.32*	-0.53**
Days to 50% flowering	G		1.00	1.00**	-0.58**	-0.59**	-0.45**	-0.70**	-0.73**	-0.64**	-0.18	-0.53**	-0.95**
	P		1.00	0.63**	-0.38*	-0.40*	-0.32*	-0.40*	-0.32*	-0.38*	0.13	-0.29	-0.60**
Days to first harvest	G			1.00	-0.97**	-0.98**	-0.85**	-0.67**	-0.82**	-0.59**	-0.10	-0.40*	-1.15**
	P			1.00	-0.34*	-0.37*	-0.34*	-0.34*	-0.26	-0.36*	-0.11	-0.21	-0.59**
Harvesting duration	G				1.00	0.97**	0.94**	-0.23	-0.16	-0.22	0.62**	0.34*	0.48**
	P				1.00	0.93**	0.87**	-0.24	-0.13	-0.16	0.13	0.27	0.49**
Number of Harvesting	G					1.00	1.00**	-0.11	-0.07	-0.10	0.58**	0.27	0.60**
	P					1.00	0.94**	-0.12	-0.05	-0.08	0.16	0.22	0.61**
Number of Fruits/ plant	G						1.00	-0.13	-0.10	-0.17	0.68**	0.13	0.57**
	P						1.00	-0.15	-0.13	-0.14	0.14	0.10	0.61**
Average fruit weight (g)	G							1.00	0.98**	0.96**	-0.51**	-0.03	0.74**
	P							1.00	0.87**	0.88**	-0.29	-0.01	0.65**
Fruit length (cm)	G								1.00	1.00**	-0.61**	0.10	0.75**
	P								1.00	0.93**	-0.25	0.11	0.52**
Fruit width (cm)	G									1.00	-0.65**	0.15	0.67**
	P									1.00	-0.34*	0.11	0.56**
Pericarp thickness (cm)	G										1.00	0.03	0.02
	P										1.00	-0.06	-0.06
Total Soluble Solids (°Brix)	G											1.00	0.07
	P											1.00	0.05
Fruit yield/plant (kg)	G												1.00
	P												1.00

* and ** significant at 5% and 1% probability level, respectively

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correlation for most of the traits. Thereby establishing dominant role of heritable factors (Singh, 2009). This indicates that the role of environment was limited in expression of these traits.

The genotypic and phenotypic association of fruit yield per plant was significantly positive with harvesting duration, number of harvesting, number of fruits per plants, average fruit weight, fruit length and fruit width. Reddy *et al.* (2013) reported similar findings for all the traits except total soluble solids which were positively correlated. A negative significant correlation was observed with days to initiation of flowering, days to 50% flowering and days to first harvest. These results suggesting that number of fruits per plant, number of harvest, harvesting duration, average fruit weight, fruit length and fruit width may be considered for selection.

Days to first harvest showed negative significant association with harvesting duration, number of fruits per plant, number of harvests and fruit length and fruit width, while, non-significant with pericarp thickness at both genotypic and phenotypic levels. A positive significant correlation was noticed between fruit width, number of harvesting, average fruit weight, pericarp thickness, T.S.S. with fruit length. Rani and Anitha (2011) reported that number of locules was positively correlated with number of fruits per plant at both level and total soluble solids at phenotypic level. Number of locules was negative but significantly correlated with plant height and fruit width.

Average fruit weight was negatively correlated with days to initiation of flowering, days to 50% flowering, days to first harvest, harvesting duration, number of harvesting and number of fruits per plants. While positively correlated with fruit width and fruit yield per plant. Similar results were also reported by Das *et al.* (1998). Days to first harvest was negatively correlated with number of fruit per plant, fruit length, fruit width, and number of locules. Number of harvest was positively correlated with number of fruit per plant. Total soluble solid was positively correlated with number of fruit per plant and negatively with pericarp thickness at phenotypic level.

The per cent disease incidence of the parents M-3-1 and H-36 at 120 DAT was observed very less *i.e.,* 8.58 and 6.25 per cent, respectively. While in F_5 generation, the per cent disease incidence at 120 DAT was very less *i.e.,* 8.19% whereas, it was very high in susceptible check Punjab Chuhhara (63.78%), and Dhanashree (55.00%) showed moderate resistance to TLCV disease at 120 DAT.

The coefficient of infection of the parent M-3-1 and H-36 at 120 DAT was observed very less *i.e.*, 0.22 and 0.21, respectively indicating resistance to TLCV while the F_5 generation showed less value (0.24) The coefficient of infection of Dhanashree at 120 DAT was 10.31, whereas, Punjab Chuhhara (susceptible check) was observed to be very high i.e., 40.98 at 120 DAT, so they are moderately resistance and susceptible, respectively. The per cent disease incidence ranged from 3.57 to 63.78 while Coefficient of infection varied from 0.03 to 40.98.

The desirable genotypes observed indicated great scope for improvement beyond normal range of parents and

Table 2. Disease Incidence and Coefficient of Infection of different genotypes in tomato

Genotype / Generation	Per cent Disease Incidence (%)			
	30 DAT	60 DAT	90 DAT	120 DAT
M-3-1	3.57 (10.89)	8.58 (17.03)	8.58 (17.03)	8.58 (17.03)
H-36	5.00 (12.92)	6.25 (14.48)	6.25 (14.48)	6.25 (14.48)
F_5	3.74 (11.15)	8.03 (16.46)	8.19 (16.63)	8.19 (16.63)
Dhanashree (Standard Check)	12.5 (20.70)	22.5 (28.32)	45 (42.13)	55 (47.87)
Punjab chuhhara (Susceptible Check)	41.56 (40.14)	58.65 (49.98)	63.78 (53.00)	63.78 (53.00)
CD (0.01)	0.98	0.66	0.95	0.90

Genotype / Generation	Coefficient of Infection				
	30 DAT	60 DAT	90 DAT	120 DAT	Reaction
M-3-1	0.03 (0.99)	0.22 (2.69)	0.22 (2.69)	0.22 (2.69)	HR
H-36	0.09 (1.72)	0.21 (2.63)	0.21 (2.63)	0.21 (2.63)	HR
F_5	0.05 (1.28)	0.22 (2.69)	0.23 (2.75)	0.24 (2.81)	HR
Dhanashree (Standard Check)	0.70 (4.80)	2.25 (8.63)	7.31 (15.69)	10.31 (18.73)	MR
Punjab chuhhara (Susceptible Check)	8.01 (16.44)	19.75 (26.39)	32.40 (34.70)	40.98 (39.80)	S

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thus extremely helpful in crop improvement programme for development of cultivar having resistance to TLCV disease along with high yield.

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Performance of Indian Mustard (*Brassica juncea* L.) in Response to Foliar Spray of Thiourea and Thioglycollic Acid Under Different Irrigation Levels

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Indian mustard (*Brassica juncea L.* Czernj. & Cosson) is predominantly cultivated in Rajasthan, UP, Haryana, Madhya Pradesh, and Gujarat. It is also grown under some nontraditional areas of South India including Karnataka, Tamil Nadu, and Andhra Pradesh. The crop can be raised well under both irrigated and rainfed conditions (DES, 2012). The irrigated area under this crop is 62% of its total cropped area. General practice of growing this crop is in the fields, which are kept fallow during rainy season to conserve moisture, and farmers also provide one or two irrigation depending on the availability of water even to the crop grown on conserved moisture. The recent research findings indicate the use of bio-regulators for increasing productivity. These bio-regulators acts as chemical catalyst in the plant and improve physiology and reproductive efficiency in the plant. These bio-regulators possibly improve the sucrose transport and increase dry matter partitioning for grain production. Thiourea and thioglycollic acid are sulphydral bio- regulators. In arid areas, despite constraints imposed by lack of water and high temperatures, the crop plants mostly survive in average rainfall years. In view of the above, it is conceivable to assume that if antioxidants are sprayed onto the crop plants, most of the damaging free radicals can be quenched and the crop plants can be able to maintain an improved metabolic energy status, which will then facilitate translocation and partitioning of assimilates for yield formation. Since sulphydryl compounds are strong antioxidants and also supply reactive sulphydryl group for the functioning of sucrose transport protein, they can more effectively improve assimilate partitioning and yield of crops under arid environment (Sharma *et al.*, 2005). Keeping in view and the paucity of information available on these aspects, a study was conducted on Indian mustard.

A study was conducted during *rabi* season of 2008 and 2009 at the farm field at Bikaner, Rajasthan, 28° 01'N latitude and 73° 22' E longitude at an altitude of 234.70 meters above mean sea level. The experiment was laid out in a split-plot design with three levels of irrigation [Water sufficient (four irrigation), water limited (two irrigation) and water deficient (pre sowing irrigation)] in main plots and nine levels [control (water spray), one foliar spray of thiourea (500 ppm) at initiation of branching, two foliar spray of thiourea (500 ppm) at initiation of branching and flowering, one foliar spray of thiourea (1000 ppm) at initiation of branching , two foliar spray of thiourea (1000 ppm) at initiation of branching and flowering, one foliar spray of thioglycollic acid (50 ppm) at initiation of branching, two foliar spray of thioglycollic acid (50 ppm) at initiation of branching and flowering , one foliar spray of thioglycollic acid (100 ppm) at initiation of branching and two foliar spray of thioglycollic acid (100 ppm) at initiation of branching and flowering] of thiourea and thioglycollic acid spray in sub-plots with four replications. Indian mustard cultivar Bio-902 was sown at a spacing of 30 cmx15 cm on 24 October in 2007 and 23 October in 2008. The soil was loamy sand having 109.50 kg available nitrogen ha^{-1}, 13.91 kg available ha^{-1} phosphorus, 165.0 kg available potassium ha^{-1}, 8.79 ppm available sulphur, pH 8.35 and organic carbon 0.059 %. In addition to irrigation applied as per treatments crop received 8 mm rainfall during 2008 and 13 mm rainfall during 2009. Data on various growth and yield attributes, grain and straw yields of mustard were calculated as per the standard procedures. The experimental data were analysed statistically by applying the technique of analysis of variance prescribed for the design to test and conclusions were drawn at 5% probability levels.

Yield attributes : Successive increase in the levels of irrigation and thiourea and thioglycollic acid spray significantly improved the all yield parameters (Table 1). The sufficient four irrigations were significantly improved the number siliqua $plant^{-1}$, siliqua length, seed $siliqua^{-1}$ and 1000 seed weight, which were significantly higher than all other irrigation levels of Indian mustard, all growth parameters increased significantly with increasing number of irrigations. These results corroborated with the results of Singh *et al.*

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(2000) and Issa and Sharma (2007). Number of iliqua plant^{-1}, siliqua length(cm), seed siliqua^{-1} and 1000 seed weight significantly improved with corresponding increase in levels of thiourea spray up to 1000 ppm and thioglycollic acid up to100 ppm at initiation of branching and flowering stages. Spray at initiation of branching and flowering stages of thioglycollic acid 100 ppm produced significantly higher growth parameters. However, the differences between thiourea and thioglycollic acid spray were statistically at par in both the years in respect of all growth parameters. These effects increased the dry matter accumulation by the crop plants, and the effects were found consistent at all the stages of growth parameters. It appears that the photosynthetic process of the crop was improved under the influence of thiourea and thioglycollic acid spray.

Seed and straw yield: Seed yield increased significantly with each successive increase in irrigation levels upto four. in both the years. The seed and straw yield in sufficient irrigations was 22.72 and 64.11 q ha^{-1} against 11.78 and 26.06 q ha^{-1} in pre sowing irrigation, respectively (Table 1). The sufficient irrigation resulted in more number of branches, longer plants and more yield attributes, which consequently helped in the production of higher straw yield and biological yield. Application of thiourea up to 1000 ppm and thioglycollic acid up to100 ppm spray at initiation of branching and flowering stages in both the years recorded significantly higher seed yield and straw yield. Spray at initiation of branching and flowering stages of thioglycollic acid 100 ppm *produced* significantly higher seed yield and straw yield. Thiourea spray up to 1000 ppm and thioglycollic acid spray up to100 ppm were statistically at par in both the years in respect of seed yield and straw yield parameters. The beneficial results were also reported by Premi, *et al.* (2004), Deshveer and Singh (2003).

Interactions: The interaction between thiourea, thioglycollic acid spray and irrigation levels was significant on seed yield of Indian mustard (Table 2). At the spray levels of thiourea up to 500 ppm and thioglycollic acid 100 ppm at initiation of branching and flowering stages, increase in spray levels significantly increased the seed yield of Indian mustard and thereafter decreased significantly at reducing rate of spray levels of thiourea and thioglycollic acid. Similarly at the same decreased irrigation levels significantly decreased seed yield up to pre-sowing irrigation. The maximum seed yield was in treatment combination four irrigation levels and thioglycollic acid 100 ppm spray at initiation of branching and flowering stages during both the years, respectively (Sharma *et al.*, 2005). The favorable effect of optimum level of irrigation, thiourea up to 500 ppm and thioglycollic acid up to 100 ppm spray at initiation of branching and flowering stages. The favorable effect of thioglycollic upt o 500 ppm and thioglycollic acid up to 100 ppm spray at initiation of branching and flowering stages, combination might be because spray is likely to make the crop more responsive to the growth. Addition of irrigation may maintain a favorable environment and balance between the applied thiourea, thioglycollic acid spray in the plant for its optimum growth.

The present studies indicate that foliar spray

Table 1. Effect of different levels of irrigations, thiourea and thioglycollic acid spray on yield attributes and yields of Indian mustard (Two year pooled data)

Treatment	No of siiqua plant^{-1}	Siliqua length (cm)	No of seeds sliqua^{-1}	1000 seed wt (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})
Water conditions						
Water sufficient (Four irrigation)	209.96	4.51	13.54	8.76	22.72	64.11
Water limited (Two irrigation)	177.21	4.15	12.47	8.19	16.48	35.67
Water deficient (Pre-sowing irrigation)	148.38	3.19	10.84	7.96	11.78	26.06
CD (*P*=0.05)	2.28	0.14	0.32	0.19	0.62	2.56
Foliar spray						
Control (water spray)	151.08	3.31	11.07	7.83	13.43	30.30
Thiourea (500 ppm) at initiation branching-One spray	178.35	3.99	12.12	8.44	17.06	42.99
Thiourea (500 ppm) at initiation branching & flowering-Two spray	194.12	4.50	13.12	8.62	18.63	46.59
Thiourea (1000 ppm) at initiation of branching- One spray	166.93	3.61	11.67	7.97	15.74	38.58
Thiourea (1000 ppm) at initiation .of branching & flowering-Two spray	178.70	3.84	12.32	8.16	17.63	43.55
Thioglycollic acid (50 ppm) at initiation of branching- One spray	169.47	3.74	11.65	8.15	15.72	39.29
Thioglycollic acid (50 ppm) at initiation of branch. & flow. -Two spray	183.24	3.83	12.37	8.33	17.38	43.33
Thioglycollic acid (100 ppm) at initiation of branching- One spray	183.20	4.09	12.65	8.49	17.77	44.17
Thioglycollic acid (100 ppm) at initiation of branch. & flow.-Two spray	201.55	4.64	13.57	8.78	19.57	48.72
CD (*P*=0.05)	13.52	0.29	0.79	0.40	0.88	2.76

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Table 2. Interaction effect levels of irrigation and foliar spray of thiourea and thioglycollic acid on seed yield (q ha^{-1}) of Indian mustard (Pooled)

Treatment	Water sufficient (Four irrigation)	Water limited (Two irrigation)	Water deficient (Pre sowing irrigation)
Control (water spray)	18.69	13.00	8.59
Thiourea (500 ppm) at initiation branching-One spray	22.75	16.68	11.76
Thiourea (500 ppm) at initiation branching & flowering-Two spray	24.67	18.10	13.12
Thiourea (1000 ppm) at initiation of branching- One spray	22.28	15.02	9.92
Thiourea (1000 ppm) at initiation .of branching & flowering-Two spray	23.72	17.49	11.69
Thioglycollic acid (50 ppm) at initiation of branching- One spray	20.91	15.50	10.76
Thioglycollic acid (50 ppm) at initiation of branch. & flow. -Two spray	22.58	16.99	12.57
Thioglycollic acid (100 ppm) at initiation of branching- One spray	23.37	16.82	13.11
Thioglycollic acid (100 ppm) at initiation of branch. & flow.-Two spray	25.56	18.67	14.49
CD (*P*=0.05)	1.38		

thiourea an thioglycollic acid with sufficient irrigation water (four irrigations) at initiation of branching and flowering stages increased the productivity of grain and straw The results also suggest that application of bio-regulators to enhance yield of mustard under arid environment.

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Effect of Additional Dose of Fertilizers on the Growth, Yield and Fruit Quality of Litchi (*Litchi chinensis* Sonn.) var. Calcuttia

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Litchi cultivation is confined to Bihar, West Bengal, Uttar Pradesh, Jharkhand, Assam, Punjab, Chhattisgarh, Uttrakhand. In India, it occupied an area of 80.4 thousand ha with annual production of 5.38 lacs Mt (Anonymous, 2011). Litchi is successfully grown in sub-mountainous region of Punjab comprising of Gurdaspur, Hoshiarpur, Pathankot and Patiala districts. Nutrient supply plays an important role in increasing productivity and quality of litchi crops. Determination of nutrient needs of litchi orchard is of utmost importance to litchi growers. Various experiments have been conducted earlier on foliar spray of micro-nutrient in different fruit crops and shown significant response to improve yield and quality of fruits by Kumar *et al.* (2004). It is also well established fact that acute shortage of nitrogen, phosphorous and potassium seems to check litchi vegetative growth and floral primordia initiation. The application of macro nutrients(N,P and K) substantially enhanced fruit yield and quality in various litchi cultivars. Micronutrients (Zn,B and Cu) also play vital role in litchi nutrition and significantly improved flowering, fruit set, fruit drop, fruit size and and fruit quality.

The present investigation was conducted at Punjab Agricultural University, Regional Research Station, Gurdaspur (Punjab) on litchi cv. Calcuttia during the years 2011 and 2012. Plants of uniform growth and good health were selected with three number of replications in each treatment. The different treatments were, T_1 (1.6 kg Urea+2.25 kg SSP+0.6 kg MOP), T_2 (T_1+0.5 kg urea during 1st week of July, T_3 (T_1+ 1.0 kg urea during 1st week of July), T_4 (T_1+ two foliar sprays of $ZnSO_4$ @0.3% in Aug. and Feb.), T_5 (T_1+ soil application of urea@ 0.5 kg during 1st week of July+ two foliar sprays of $ZnSO_4$ @0.3% during Aug. and Feb.), T_6 (T_1+ soil application of urea @ 1.0 kg during 1st week of July+ foliar sprays of $ZnSO_4$ @0.3% in Aug. and Feb.) and T_7 as control (No fertilization). Vegetative growth characters tree spread (N-S and E-W), trunk girth (cm) and tree volume (m^3) of the plant were recorded annually in January before the start of flowering season. The four branches growing uniformly in different directions were tagged at the time of fruit set in each replication. Fruit yield was calculated by multiplying total number of fruits with average fruit weight and expressed in kg/tree at the time of fruit harvest. Physical characteristics (fruit colour, fruit length, fruit breadth, fruit weight , pulp weight, seed weight and peel weight) were also recorded as per standard procedure. Total soluble solids (TSS) of the fruit juice was determined with Refractometer (Brand) and expressed in per cent (%) TSS after correction at 20° C. The fruit colour was judged with the help of Royal Horticultural Colour Chart. The titrable juice acid content in maleic acid was determined as per A.O.A.C. (2000).

It is evident from the data that tree spread (N-S and E-W) in different treatments was found statistically non-significant (Table 1), however higher trunk girth (125.1 cm in

Table 1. Effect of additional dose of fertilizers on the growth and yield of litchi *(Litchi chinensis* Sonn.) var. Calcuttia

Treatments	Girth (cm)		Height (m)		Spread (m)		Tree Volume (m^3)	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	105.1	109.0	7.1	7.5	8.5	8.9	24.6	27.8
T_2	110.0	119.2	7.2	7.6	8.2	8.5	27.3	33.6
T_3	106.0	108.7	5.8	6.2	7.6	7.9	20.6	22.8
T_4	117.3	128.1	7.3	7.8	7.9	8.1	31.5	39.9
T_5	125.1	133.1	6.5	6.8	8.4	9.2	25.4	37.7
T_6	108.2	111.3	6.7	6.9	8.3	9.0	24.5	26.5
T_7	105.2	107.7	7.1	7.4	7.9	8.1	24.7	26.6
CD (P=0.05)	8.4	NS	2.5	1.2	NS	NS	2.4	3.0

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2011 and 133.1 cm in 2012) was recorded in T_5 followed by T_4. The minimum plant girth was recorded to be in control (105.2 cm) which was at par with T_1 treatment. Significant differences were observed among the different treatments with regard to plant height and tree volume, the maximum plant height and tree volume were observed in T_4 (7.3 m plant height, 31.5 m^3 tree volume in 2011 and 7.8m plant height, 39.9 m^3 tree volume in 2012). These findings are in agreement with the results of Sharma *et al.* (2005) in Ber cv. Umran. The highest fruit yield (93.2 kg per tree) was recorded in T_6 followed by T_5 (90.4 kg/ tree) and minimum in T_7. Similarly, these results are in accordance with the findings reported by Sindhu *et al.* (1999), they observed that the urea alongwith the spray of zinc sulphate subtantially increased bunch weight, yield and soluble solids in grapes. Maximum fruit breadth,weight and soluble solids were noticed in T_6 and minimum in T_7 (Table 2). These findings are corroborated with the observations of Kumar and Pathak (1992) who reported that urea as foliar feeding improved fruit size, weight, yield and fruit quality attributes in grapes. However, the differences among different treatments in terms of fruit peel and stone weight were statistically non-significant. The values recorded for total soluble solids and juice acid content were statistically at par with each other except T_7.

Fruit juice acid content was decreased with the application of higher doses of urea and zinc sulphate. Likewise, the intensity of fruit colour among different treatments was almost remained the same except T_7 (control), where the colour development was very poor (Table 3). The data mentioned in Tables 1-3, depicted that fruit

Table 2. Effect of additional dose of fertilizers on the fruit physical characteristics of litchi *(Litchi chinensis* Sonn.) var. Calcuttia

Treatments	Yield (kg per tree)		Fruit weight (gm)		Fruit length (cm)		Fruit breadth (cm)		Pulp weight (gm)		Seed weight (g)		Peel weight (g)	
	2010-11 (off year)	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	8.6	61.3	18.5	17.6	3.5	3.6	3.2	3.2	15.0	14.0	2.3	2.3	1.2	1.4
T_2	6.5	74.6	19.5	18.5	3.6	3.6	3.5	3.3	15.2	14.4	2.9	2.8	1.4	1.3
T_3	10.4	76.2	20.0	19.0	3.6	3.7	3.5	3.4	16.0	15.1	2.5	2.5	1.5	1.4
T_4	5.3	81.6	20.5	20.5	3.7	3.7	3.3	3.5	16.4	16.0	2.7	2.7	1.4	1.5
T_5	7.7	90.4	21.0	21.5	3.8	3.8	3.4	3.6	17.2	17.8	2.4	2.3	1.5	1.4
T_6	6.3	93.2	21.5	22.7	4.2	4.0	3.6	3.8	17.4	18.7	2.7	2.5	1.4	1.4
T_7	7.2	55.1	16.5	16.7	3.4	3.5	2.5	2.7	12.4	12.8	2.6	2.5	1.4	1.4
CD (5%)	NS	4.3	2.1	2.1	0.4	0.3	0.6	0.5	0.9	0.9	NS	NS	NS	NS

Table 3. Effect of different doses of fertilizer application on the TSS, acidity and colour of litchi *(Litchi chinensis* Sonn.) fruit var. Calcuttia

Treatments	TSS (%)		Acidity (%)		Fruit colour	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
T_1	18.2	18.0	0.5	0.5	50% Pinkish red	50% Pinkish red
T_2	18.3	18.0	0.5	0.5	65% Pinkish red	60% Pinkish red
T_3	18.3	18.1	0.5	0.4	70% Pinkish red	75% Pinkish red
T_4	18.3	18.0	0.4	0.4	75% Pinkish red	80% Pinkish red
T_5	18.2	18.1	0.4	0.4	80% Pinkish red	80% Pinkish red
T_6	18.3	18.1	0.4	0.4	90% Pinkish red	95% Pinkish red
T_7	14.1	14.7	0.8	0.9	10% Pinkish red	20% Pinkish ed
CD (5%)	0.2	0.5	NS	NS	-	-

yield, fruit weight, fruit length, fruit breadth, pulp weight, TSS were highest in T_6 as compared to other treatments. These results are in line with those reported by Kumar *et al.*(2004) on litchi cv. Dehradun and Kassem *et al.* (2011) in jujube tree, Meena *et al.* (2005) in guava and Khyyat *et al.*(2007) in date palm.

It is concluded that the application of recommended dose of fertilizers along 1.0 kg urea in first week of July + foliar spray of $ZnSO_4$ @ 0.3% in August and February to the litchi plant significantly improved the fruit yield and quality.

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Effect of Spacing on Growth, Seed Yield and Tuber Yield of Glory Lily (*Gloriosa superba* L.)

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Glory lily (*Gloriosa superba* L.) native to tropical Asia and Africa is an important medicinal crop and is currently distributed extensively throughout the tropics as a potted plant. In India, it is usually found in Himalayan foot-hills, central India, Tamil Nadu, Andhra Pradesh, Karnataka and West Bengal. The seeds are exported to Europe, USA, Australia and African companies based in Nigeria, Cameroon and Zimbabwe for extraction of phytochemicals, coclchicine and its derivatives and to use in pharmaceutical industry (Anonymous, 2012). The phytochemicals present in glory lily have analgesic, anti-inflammatory, antithrombotic, enzyme inhibitory, anti-venom and chemotherapeutic potential. The tubers and other parts of this plant are used in Indian system of medicines for different purposes.

There is very little variability available for seed yield and colchicine content in glory lily. Hence the only way to improve the yield is through manipulation of plant population under cultivation. However, in glory lily, there is no standardized scientific spacing recommendation available, as the work on this crop is very meager. The farmers adopt spacing based on their personal experiences and this lacuna eventually results in low productivity. In this regard, an investigation was taken up with an objective to study the effect of different spacings on growth, seed and tuber yields of glory lily.

The study was carried out in the farmer's field at Antravalli, Kumta taluka of Uttar Kannada district (Karnataka) from June, 2012 to January, 2013. There were eight treatments with different spacings viz. 60 x 30 cm, 60 x 60 cm, 90 x 30 cm, 90 x 60 cm, 120 x 30 cm, 120 x 60 cm, 150 x 30 cm, 150 x 60 cm. The experiment was laid out in randomized block design with three replications. Good quality and healthy tubers (weighing approx. 50g each) were selected for plating. Observations on growth and yield parameters were recorded in five randomly selected uniform plants and labeled.

In present study, the vine length was highest (153.61cm) in 90 x 60 cm spacing and it was on par with with a spacing of 90 x 30 cm (Table 1). The lowest vine length (102.87 cm) was observed in 150 x 60 cm spacing. The increased vine length in closer spacing is due to linear growth of the vine which might be due to the inter plant competition for space and light as a result of higher plant density. These results are in accordance with findings of Mastiholi (2008) and Jayalakshmi (2003) in coleus, Akhani et al. (2012) in coriander and Taleie et al. (2012) in stevia. Jayalakshmi (2003) reported the increased stem girth in wider spacing but in the present study, the highest stem girth (6.32 mm) was recorded in 60 x 60 cm spacing and was on par with 150 x 60 cm spacing. The lowest value for stem girth was in 120 x 60 cm spacing. On an average, crop took 70.71 days for flower initiation. The flower initiation was earlier (68.67 days) in 90 x 30 cm spacing. The possible reasons may be the induction of stress for nutrients and water and thus early flowering under closer spacing compared to wider spacing. The number of days for flower initiation was statistically on par with 60 x 30 cm, 90 x 60 cm, 120 x 30 cm and 150 x 60 cm spacings.

The number of flowers per plant ranged from 7.8 to 15.07 in 150 x 60 cm and 90 x 60 cm spacing, respectively. The number of flowers per plant was statistically on par in 60 x 60 cm, 90 x 30 cm, 90 x 60 cm, 120 x 30 cm and 120 x 60 cm spacings. The increase in number of flowers may be the consequence of better growth and branching with more number of flowering shoots under closer spacing. Though the number of flowers per plant was statistically on par in T_2 to T_8 spacings, 90 x 30 cm (T_3) spacing recorded significantly increased number of pods per plant (10.67) and lowest (4.73) was in 150 x 60 cm spacing. Similarly, the per cent fruit set was also significantly higher (78.47) in 90 x 30 cm spacing followed by 60 x 30 cm where as lowest (59.85) per cent fruit set was recorded in 120 x 30 cm spacing. The results are in conformity with Akhani *et al.* (2012) in coriander and Sundareswaran *et al.* (2012) in ambrette. The decrease in yield contributing characters in closer spacings (60 x 30 and 60 x 60 cm) might be due to higher interplant competition which limited the availability of nutrients and light. As far as

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Table 1. Effect of spacing on growth and yield characters of

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Table 1. *Effect of spacing on growth and yield characters of glory lily (Gloriosa superba L.)*

Treatment	Vine length (cm)	Stem girth (mm)	Days to flower initiation	No. of flowers per plant	No. of pods per plant	Fruit set (%)	No. of seeds per pod	Yield per ha (q)		
								Fresh seed	Dry seed	Tuber
60 x 30cm	108.08	5.35	70.67	8.87	6.60	74.43	58.27	12.45	1.82	18.64
60 x 60cm	128.95	6.32	69.33	13.33	9.07	68.02	61.07	8.53	1.27	9.67
90 x 30cm	143.39	5.74	68.67	13.73	10.67	78.47	59.80	14.28	2.04	16.34
90 x 60cm	153.61	5.70	71.67	15.07	9.00	61.12	59.33	5.74	0.86	7.68
120 x 30cm	125.49	5.22	75.33	14.2	8.47	59.85	60.67	8.69	1.26	10.15
120 x 60cm	138.36	5.08	69.67	12.13	8.00	66.66	57.07	4.04	0.61	4.61
150 x 30cm	117.39	5.63	69.00	9.47	6.07	64.09	59.20	4.76	0.69	5.51
150 x 60cm	102.87	5.78	71.33	7.8	4.73	60.49	59.47	1.95	0.30	2.84
CD (0.05)	14.62	0.57	5.49	3.05	1.45	9.02	2.31	1.41	0.19	2.96
CV (%)	6.56	5.83	4.43	14.74	10.6	7.73	2.23	10.67	9.93	17.91

the number of seeds per pod is concerned, 60 x 60 cm (T_2) spacing showed the highest number of seeds per pod (61.07) which was on par with other treatments except 60 x 30 and 120 x 60 cm spacings.

There was increase in fresh seed yield with decrease in spacing up to 90 x 30 cm. Further decrease in spacing did not show increase in fresh seed yield. The estimated fresh seed yield per hectare was statistically superior (14.28 q) in 90 x 30 cm spacing and lowest (1.95 q) in 150 x 60 cm spacing. The longer vines, more number of branches and early flowering due to better growth and increased number of pods per plant due to increased cross fertilization have been contributed to higher fresh seed yield in closer spacing. The similar trend was observed in dry seed yield also. The mean dry seed yield per ha was 1.11 q. The estimated dry seed yield per hectare has shown significantly higher values at 90 x 30 cm followed by 60 x 30 cm spacing. The 150 x 60 cm spacing recorded the lowest dry seed yield per ha. Akhani *et al.* (2012) reported the highest seed yield in coriander at a plant population of 25 plants per m^2. Sundareswaran *et al.* (2012) also reported the decreased yield in closer spacing (60 x 30 cm) in ambrette. The mean tuber yield per ha was 9.43 q and there was statistically significant difference among the spacing levels. The tuber yield increased with decrease in spacing. There was highest estimated tuber yield per ha (18.64 q) in 60 x 30 cm spacing which was on par with 16.34 q in 90 x 30 cm. The lowest was in 150 x 60 cm spacing. The significant increase in tuber yield per ha was due to optimum plant population and better growth of tubers which resulted in increased tuber weight. Patel *et al.* (2008) reported the highest tuber yield per ha in safed musli at closer spacing (30 x 15cm). Similar results were obtained by Ramchandra and Jha (2003) and Kothari and Reddy (2009) in safed musli and Veeraraghavathatham *et al.* (1985) and Patil and Hulamani (1999) in coleus. A closer spacing helps in increased cross fertilization thereby increasing pod set and thus yield. The maintenance of optimum plant population will pave a way to maximize the seed yield. In conclusion one can infer that the glory lily planted at 90 x 30 cm spacing results in better plant growth, increased seed and tuber yields under coastal environment of Karnataka.

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Assessment of Shelf Life of Garlic (*Allium sativum* L.) Ecotypes

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Among the spices grown in India, garlic (*Allium sativum* L.) is the most important bulbous crop and widely cultivated *Allium* throughout country. It is consumed in both vegetarian and non-vegetarian dishes and valued highly for its characteristic flavour (Roy and Chakraborti, 2002). The successful storage of garlic bulbs depends upon the variety, maturity, cultural practices and post-harvest handling (Sidhu, 2008). Water loss, sprouting and post harvest diseases caused considerable deterioration in quality of stored bulbs and the contribution of each of these components to the total weight loss varies between different cultivars.

The lack of high yielding and better storage varieties of garlic are the main constraints limiting the production and productivity. Garlic exhibits greater susceptibility to agro-techniques and environmental condition and possesses a wide range of variability for bulb traits and yield attributes as well as the storability in spite of being vegetatively propagated crop. To meet out the domestic as well as export requirement, selection of suitable genotypes for growing under different agro-climatic conditions and better self-life is required. However, very less attention have been paid by plant breeders on this aspect. Thus, the present investigation was conducted to evaluate garlic genotypes for storability under Punjab conditions.

The experiment was conducted to study the performance of 45 garlic clones under ambient storage conditions at Vegetable Research Farm of Punjab Agricultural University, Ludhiana. The crop was harvested in April. These were thoroughly sorted to remove all damaged, injured, split, off-type and diseased bulbs. Each lot consists of 25 uniform bulbs and stored in netted nylon mesh bags and kept in ventilated room storage at ambient temperature in well spaced stacks for five months beginning from May to September end. The sample lots were arranged in a completely randomized design (CRD) with three replications. The data was recorded at 30 days interval starting from May upto September end. The mean temperature range during experiment was 25 to 32°C and relative humidity between 45 to 85%. The bulbs were critically examined for three parameters viz. physiological loss in weight (PLW), rotting incidence and sprouting percentage. The initial weight of all the samples was recorded before putting in the storage. The data were analyzed using the analysis of variance procedure.

No sprouting was observed during the entire storage period i.e. from May to September, however considerable losses were observed due to physiological loss in weight (PLW) and rotting incidence (Table 1 and 2).

After one month of storage, genotype AVTG-1 (0.25) and AVTG-4 (0.25) showed minimum physiological loss in weight, while maximum physiological loss in weight was observed in BG-107 (0.73), but it did not show significant differences (Table 1). A significant difference was observed among all the genotypes for physiological loss in weight after two months of storage. Minimum physiological loss in weight was reported in AVTG-4 (1.23) followed by other 36 genotypes, while maximum physiological loss in weight was observed in BG-107 (3.63). After three months of storage the minimum physiological loss in weight was noted for PG-18 (5.56) and maximum was found in JGL-96-1988 (16.44), followed by AVTG-10 (15.89). After four months of storage, the minimum physiological loss in weight was noted for PG-31 (11.59), which was at par with PG-19 and AVTG-4 (12.32). Maximum physiological loss in weight was observed in AVTG-10 (25.61), followed by BG-107 (25.46). After five months of storage the minimum and significant physiological loss in weight was observed in PG-31 (15.94), while, maximum physiological loss in weight was observed in JGL-96-1988 (30.66), followed by BG-107 (30.30) and IETG-5 (30.04).

The storage data pertaining to rotting incidence have been presented in Table (2), which revealed that there was no incidence of rotting in all the genotypes after one month of storage except DARL-52 (13.34). After two months of storage 24 genotypes resulted in no incidence of rotting, however highest rotting incidence was observed in DARL-52 (24.00). After three months of storage the minimum rotting incidence was noted for PG-20 (0.00) and AG-102 (0.00), while maximum was found in DARL-52 (48.00). After four months of storage the minimum rotting incidence was noted

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Table 1. Physiological loss in weight (%) during storage in garlic

Genotypes	Storage intervals					Mean	TSS (°Brix)	Dry matter (%)
	I_1 (30 days)	I_2 (60 days)	I_3 (90 days)	I_4 (120 days)	I_5 (150 days)			
PG-9	0.44	2.22	13.35	20.03	26.70	12.55	43.93	37.86
PG-19	0.32	1.61	7.60	11.80	19.67	8.20	37.57	38.35
PG-24	0.36	1.77	9.69	14.05	20.48	9.27	42.60	41.50
AVTG-5	0.36	2.03	13.60	19.72	25.50	12.25	33.10	36.63
G-282	0.31	1.56	11.71	16.14	22.39	10.42	44.60	42.73
PG-31	0.28	1.45	7.24	11.59	15.94	7.30	40.07	41.50
IETG-6	0.35	1.76	11.08	19.36	28.21	12.15	41.33	38.88
IETG-4	0.43	2.18	14.14	20.26	23.24	12.05	36.10	38.48
IETG-9	0.38	1.91	10.91	20.23	23.29	11.35	47.87	38.69
IETG-5	0.49	2.48	13.57	22.18	30.04	13.76	39.80	40.05
IETG-2	0.35	1.75	8.17	12.85	19.29	8.48	36.38	40.08
IETG-1	0.35	1.75	8.17	12.85	19.29	8.48	46.34	39.33
AVTG-1	0.25	1.24	8.61	13.57	17.50	8.24	39.77	35.10
AVTG-2	0.32	1.59	10.59	14.26	19.81	9.32	38.50	36.63
AVTG-4	0.25	1.23	9.46	12.32	18.11	8.27	32.80	38.50
AVTG-6	0.34	1.71	12.76	22.25	26.03	12.62	29.10	37.47
AVTG-7	0.33	1.64	10.64	18.85	22.39	10.77	38.50	38.10
AVTG-10	0.44	2.22	15.89	25.61	28.95	14.62	20.03	33.66
JGL-96-1988	0.53	2.67	16.44	19.98	30.66	14.06	40.03	33.94
JGL-03-263	0.55	2.74	15.52	21.94	28.76	13.90	39.37	35.74
JNDG-213	0.35	1.75	13.45	22.53	27.19	13.05	30.10	39.08
JNDG-219	0.38	1.93	12.21	19.62	24.43	11.71	35.37	39.73
AC-50	0.42	2.03	11.11	18.53	24.25	11.27	45.67	42.61
AC-200	0.41	2.03	11.11	20.19	28.32	12.41	41.33	34.80
DARL-52	0.35	1.75	11.69	20.47	27.19	12.29	24.00	34.10
NRCRG-1	0.32	1.59	9.59	14.32	23.99	9.96	48.17	40.97
RAUG-5	0.31	1.56	9.29	14.32	20.40	9.18	35.20	34.71
PG-3	0.37	1.83	9.37	18.19	22.43	10.44	31.10	37.34
PG-20	0.31	1.54	5.62	12.77	19.39	7.93	48.10	41.50
PG-1	0.40	2.02	10.33	19.35	25.96	11.61	37.03	38.71
PG-17	0.41	2.07	11.36	14.39	20.64	9.77	33.57	36.60
PG-32	0.35	1.74	9.55	18.27	22.59	10.50	35.40	38.11
PG-12	0.34	1.68	10.64	15.68	20.45	9.76	49.10	41.26
PG-18	0.27	1.39	5.56	13.65	18.52	7.88	21.47	39.39
PG-35	0.27	1.35	8.11	12.61	17.34	7.94	20.17	41.49
G-189	0.29	1.46	9.52	16.66	20.45	9.67	31.97	37.61
PG-26	0.33	1.67	10.55	18.34	22.77	10.73	48.10	40.23
PG-30	0.47	2.38	13.48	20.63	25.39	12.47	38.50	38.05
PG-33	0.44	2.22	15.34	22.23	27.41	13.53	47.97	16.50
PG-282	0.43	2.17	11.59	20.28	26.45	12.18	34.63	42.11
G-1	0.33	1.65	8.54	13.50	17.35	8.27	48.03	45.16
G-50	0.39	1.98	9.57	18.47	24.43	10.97	23.50	36.19
AG-102	0.38	1.94	9.71	19.42	26.53	11.59	38.50	35.14
BG-107	0.73	3.63	14.54	25.46	30.30	14.93	40.10	40.10
BG-108	0.36	1.79	10.58	20.36	24.49	11.52	39.20	40.25
Mean	0.37	1.88	10.92	17.78	23.44		37.65	38.11

C D (0.05) Genotypes (G)= 0.257, Storage intervals (I)= 0.858, GI=0.575 ; CV= 3.26

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Table 2. Rotting incidence (%) during storage in garlic

Genotypes	Storage intervals					
	I_1 (30 days)	I_2 (60 days)	I_3 (90 days)	I_4 (120 days)	I_5 (150 days)	Mean
PG-9	0.00	0.00	4.00	12.00	16.00	6.40
PG-19	0.00	4.00	8.00	16.00	32.00	12.00
PG-24	0.00	4.00	8.00	12.00	20.00	8.80
AVTG-5	0.00	4.00	8.00	13.34	20.00	9.06
G-282	0.00	4.00	8.00	12.00	20.00	8.80
PG-31	0.00	4.00	8.00	16.00	28.00	11.20
IETG-6	0.00	4.00	8.00	16.00	24.00	10.40
IETG-4	0.00	8.00	16.00	36.00	56.00	23.20
IETG-9	0.00	8.00	13.34	24.00	32.00	15.47
IETG-5	0.00	0.00	8.00	32.00	48.00	17.60
IETG-2	0.00	0.00	8.00	16.00	28.00	10.40
IETG-1	0.00	0.00	8.00	16.00	28.00	10.40
AVTG-1	0.00	0.00	8.00	12.00	20.00	8.00
AVTG-2	0.00	0.00	8.00	20.00	36.00	12.80
AVTG-4	0.00	0.00	8.00	12.00	16.00	7.20
AVTG-6	0.00	0.00	12.00	28.00	40.00	16.00
AVTG-7	0.00	4.00	12.00	28.00	48.00	18.40
AVTG-10	0.00	4.00	8.00	16.00	28.00	11.20
JGL-96-1988	0.00	8.00	16.00	24.00	28.00	15.20
JGL-03-263	0.00	4.00	12.00	20.00	24.00	12.00
JNDG-213	0.00	8.00	16.00	32.00	56.00	22.40
JNDG-219	0.00	4.00	8.00	36.00	56.00	20.80
AC-50	0.00	0.00	4.00	8.00	20.00	6.40
AC-200	0.00	0.00	8.00	16.00	28.00	10.40
DARL-52	13.34	24.00	48.00	72.00	96.00	50.67
NRCRG-1	0.00	0.00	8.00	12.00	20.00	8.00
RAUG-5	0.00	0.00	4.00	8.00	12.00	4.80
PG-3	0.00	0.00	4.00	12.00	16.00	6.40
PG-20	0.00	0.00	0.00	8.00	20.00	5.60
PG-1	0.00	8.00	16.00	24.00	36.00	16.80
PG-17	0.00	0.00	8.00	16.00	20.00	8.80
PG-32	0.00	0.00	8.00	12.00	16.00	7.20
PG-12	0.00	0.00	4.00	12.00	24.00	8.00
PG-18	0.00	0.00	4.00	8.00	12.00	4.80
PG-35	0.00	0.00	8.00	16.00	28.00	10.40
G-189	0.00	8.00	16.00	20.00	36.00	16.00
PG-26	0.00	0.00	8.00	16.00	32.00	11.20
PG-30	0.00	0.00	8.00	12.00	20.00	8.00
PG-33	0.00	4.00	8.00	16.00	24.00	10.40
PG-282	0.00	8.00	12.00	24.00	32.00	15.20
G-1	0.00	0.00	4.00	16.00	24.00	8.80
G-50	0.00	0.00	8.00	16.00	24.00	9.60
AG-102	0.00	0.00	0.00	4.00	8.00	2.40
BG-107	0.00	8.00	16.00	32.00	48.00	20.80
BG-108	0.00	4.00	8.00	24.00	40.00	15.20
Mean	0.29	3.02	9.45	18.96	29.78	

C D (0.05) Genotypes (G)= 0.193, Storage intervals (I)= 0.644, GI=0.432; CV= 2.17

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in AG-102 (4.00) and maximum was observed in DARL-52 (72.00). After five months of storage the minimum and significant rotting incidence was observed in AG-102 (4.00). Whereas, maximum rotting incidence was observed in DARL-52 (96.00). Earlier workers viz. Shaha *et al.* (1992), Brar *et al.* (1994), Kumar *et al.* (1995), Sidhu (2008) and Dubey and Singh (2012) also reported similar variation in storage life of onion and garlic and such variation in shelf life in different cultivars was due to genetic differences only (Kumar *et al.*, 1989).

From the study it may be conducted that the lines PG-31, RAUG-5 and AG-102 can be used for development of good quality planting material for long term storage. The genotypes PG-31, RAUG-5 and AG-102 showed high total soluble solids and dry matter content and also gave minimum losses after five months of storage which implies that the genotypes having high total soluble solids and dry matter content can be stored for long duration of time in storage godowns.

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Food Safety Practices of Slum Dwellers in Ludhiana

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Food Safety is the assurance that food will not cause harm to the consumers when it is prepared or eaten. Food safety scenario in India reveals that Indian people are aware of the risks involved with food. The retail concentration is very low in India. There are standards and guidelines, but the 'street trade' cannot be controlled. In India, the low level of food hygiene stems from poor infrastructure, a lack of technology, and shortcomings in education. Development programs have previously focused more on quantity than quality in production. India is a price-critical country where price is a higher priority than quality. On the other hand, there is a consuming middle class that wants to buy products that are perceived as quality products.

Poor food handling and hygiene practices in the domestic kitchen are thought to cause a significant number of food borne illnesses. Surveys of food borne disease outbreaks worldwide have shown that most cases of food borne diseases occur in handling food during preparation whether in homes or in food sector. Most cases of food borne illnesses are preventable if food protection principles are followed from production to consumption. Between 50 and 87 per cent of the reported outbreaks of food borne illnesses are associated with food prepared at home (Redmond and Griffith, 2003) .

A significant proportion of food borne illnesses arises from preparations in the home kitchen. Home food preparers are the final line in defense against food borne illnesses. In over 90% of households in India, it is the women who are involved in the preparation of meals. Their role in ensuring food safety and hygiene at household level is pivotal. An understanding of the status of their food handling knowledge and practices is needed. So, the role of mothers in ensuring food safety at homes is well accepted (Subba *et al.*, 2008). Adequate nutrition during infancy and early childhood is essential to ensure the growth, health, and development of children to their full potential. In order to ensure food safety; consumers need to follow certain rules at the stages of keeping/storing, preparing, cooking and serving food, starting from purchasing it. Thus, home food preparers need to know the techniques to minimize the presence of pathogens in food.

Poor children's feeding practices can lead to malnutrition which is a major public health problem in developing countries. Under nutrition is associated with 35% of child death. It is also major disabler preventing children to survive from reaching therefore potential development. The effects of poor nutrition continue throughout their life, contributing to poor school performance, reduced productivity and impaired intellectual and social development. Nearly 20 million children under 5 suffer from severe acute malnutrition. Adequate nutrition during infancy and early childhood is essential to ensure the growth, health and development of children (WHO, 2011). Inappropriate feeding practices and their consequences are major obstacles to sustainable socio-economic development and poverty reduction. Malnutrition has been responsible directly or indirectly for 60 per cent of the 10.9 million deaths annually among children under 5 (Israel and Glenn, 2009).

Several studies have revealed that the mothers' level of education has a positive impact on her knowledge and how she deals with child health care issues. Providing nutritional and health education to the infant's mothers should be helpful for improving infant's feeding pattern and ensuring the adequate growth and development of infants (Yin, 2009).

The present study was undertaken to see the impact of nutrition counseling on food safety practice score of respondents belonging to slum areas of Ludhiana. The methodology used for the study included the survey of 150 young mothers (children below 5 years). A random selection of 10 slums in Ludhiana city was made and from each slum 15 young mothers were randomly selected, thus, making the sample of 150 young mothers.

Data was collected by personally administering the questionnaire to the mothers of slum areas pertaining to feeding practices of the respondents regarding various concepts of food safety. Total 13 questions were framed regarding food safety issues the respondents were asked to

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rate these statements on the basis of regularity of following the practices from 'Always' to 'Never'. For the analysis of food safety feeding practices, response of 'Always' was given a score of 5 and 'Never' was given a score of 1. For the purpose of finding out the relation between food safety practice score and incidence of food borne diseases, correlation analysis was used. For the purpose of analyzing the overall food safety feeding practices of the respondents, the scores thus obtained from the statement of feeding practices were added for every respondent and have been termed as 'Practice Score'. Maximum possible practice score for all the statements (thirteen) related to food safety could be 65.

Nutrition counseling was imparted to the subjects for a period of three months through the lecture cum discussion methods with the help of audio visual aids. The feeding practices of the respondents pertaining to food safety were assessed before and after imparting nutrition counseling .

Food Safety Practice Score: It is worth mentioning that the results available from the study have been analyzed on the basis of various parameters pertaining to the profile of the respondents i.e. age, family size and family income. As the respondents were mothers of children (<5 yrs), so in order to assess their food safety practices, their feeding practices were analyzed as they were involved in the preparation, serving, feeding and storage of food. The children were too young to eat on their own, so it was the main responsibility of the mothers to feed the child. The results obtained from the subjects regarding their feeding practices about the food safety issues before and after the nutrition counseling are discussed below:

Food Safety Practice Score (Pre Intervention): The results of feeding practices before nutrition counseling revealed that the respondents were following various practices on regular basis were proper washing of utensils with the highest mean score of 4.2, regular cutting of nails (3.87), tying of hair while working in kitchen (3.73). The food safety practices that were rarely followed by the respondents were: giving leftover food to child (1.53), anybody else feeding the child if mother is not available (1.47), preparing child's milk in morning itself and add sugar to it (1.33), boiling of water before consumption (1.07).

Detailed analysis of the 'Practice Score' according to various parameters such as age, family income and family size has been presented in Table 1. It can be seen from the table that out of the possible maximum score 65, the mean Practice Score for all the respondents came out to be 26.40. Thus, indicated that the respondents covered under the study were having below average performance when it came to following good food safety practices.

There was a significant difference in the mean practice score of categories based on the age. The food safety practices being followed between 24-26 years were given the mean Practice Score of 27.50 which is highest among all 3 categories followed by 21-23 years i.e. 26.67 and 27-29 years (24).

Further it can be seen from the table that the highest mean Practice Score was acquired by the respondents having monthly income of Rs. 1000-1500 (27) and the respondents in large families (27.25) as compared to other categories. A comprehensive consumer survey in 2002 reveled that women, lower income households, people 65years and older practiced safer food handlings than men, higher income households and people younger than 65 years (Li-Cohen and Bruhn, 2002).

Food Safety Practice Score (Post Intervention): After imparting nutrition counseling for 3 months, the feeding practices of the respondents was again enquired by administering the questionnaire with 13 statements related to the feeding practices pertaining to food safety. The results revealed that the respondents followed the food safety practices on regular basis were washing of utensils and cutting of nails with the highest mean score of 4.87, tying of hair while working in kitchen (4.67), feeding the child immediately after making the food/milk (3.33). There were few food safety practices that were followed rarely by the respondents were preparing child's milk in morning itself and add sugar to it (1.2), boiling of water before consumption (1.07). These practices were still not above average due to the scarcity of resources among the respondents belonging to slum areas.

Detailed analysis of the 'Post Practice Score' i.e. practice score after imparting nutrition counseling for 3 months, according to various parameters such as age, family income and family size has been presented in Table 1. It can be seen from the table that out of the possible maximum score 65, the mean Practice Score for all the respondents came out to be 29.93. Thus, indicating that after nutrition counseling, the respondents were having an average performance(but better than before nutritional counseling) when it came to following the good safety practices . There was a significant difference in the mean practice score of groups based on the age. The food safety practices being followed by 21-23 years was 31 which is highest among all 3 categories followed by 24-26 years (30.38) and 27-29 years (28.25).

Further it can be seen from the table that the respondents having monthly income of Rs 1600-2000 (30.33) and with large families (31) had the highest mean Practice Score as compared to other groups.

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Table 1 Practice score

(N=150)

Category	Pre Intervention		Post Intervention	
	Mean score± S E	F-value	Mean score± S E	F-value
Total (n=150)	26.40 ±0.215	-	29.93± 0.246	-
Age				
21-23 (n=30)	26.67 ± 0.487	34.254**	31.00± 0.401	10.105**
24-26 (n=80)	27.50 ± 0.252		30.38 ±0.369	
27-29 (n=40)	24.00 ±0.253		28.25 ±0.347	
Family income				
1000-1500 (n=20)	27.00 ± 0.459	.892	29.00 ±0.688	0.221
1600-2000 (n=60)	26.50 ± 0.268		30.33 ±0,316	
More than 2000 (n=70)	26.14 ±0.378		29.86 ±0.4043	
Family size				
Large (n=80)	27.25 ± 0.256	8.378**	31.00± 0.276	13.194**
Small (n=70)	25.43 ±0.321		28.71± 0.374	

** Significant at 1%

A significant positive relationship was observed between improvement in nutritional status of ≤ 5 years children and adoption of proper infant-feeding practices by their mothers. Adolescent girls, pregnant and lactating mothers and also elderly women should be educated for promotion and protection of optimal infant-feeding practices for improving nutritional status of children. (Dinesh *et al.*, 2006).

The paired t-test was applied to find out the difference in the pre and post feeding practice scores of the respondents. Even though there were limited resources present to put the knowledge in practice and the results reveals that there was a significant difference in the pre and post feeding practices of the respondent's i.e. 0.153 ($p<0.05$). This shows that the impact of nutrition counseling was effective as it improved the practices of the young mothers (children below 5 years). A study conducted in Nepal emphasizes an appropriate mix of health education and food supplements to improve the number of children who meet the recommended infant feeding guidelines, reduce under nutrition and improve the survival rates of young children (Khanal *et al.*, 2013) . Nutrition training of health workers can help to reduce child's under nutrition. Specifically, trained health workers might contribute to this end through frequent nutrition counseling of caregivers. This may improve child-feeding practices and thus reduce the risk of under nutrition among children of counseled caregivers (Sunguya *et al.*, 2013).

Correlation between feeding practices and incidence of food borne diseases: A significant negative correlation was found between feeding practices and incidence of food borne disease with a coefficient of -0.297 ($p<0.05$) among all the respondents included in the study. This show with improvement in feeding practices there was a decrease in food borne disease prevalence among children. A study was conducted in Melbourne, Australia in which the cases of gastroenteritis were examined to identify if dietary intake prior to an episode and food-handling and storage practices in the home were risk factors for illness. Although food-handling and storage practices were considered important, but no association was detected in the study(Mitakakis *et al.*, 2004). The results of another study suggested that food-hygiene practices of mothers in the home had a potential impact on the prevention of diarrhea. The improvement of food-hygiene practices of mothers could be an effective strategy to prevent diarrhea among children (Kumiko *et al.*, 2009).

- From present studies it can be concluded that imparting nutrition counseling for the period of 3 months helps to improve the feeding practices pertaining to food safety and there was a significant negative correlation between food safety practices and incidence of food borne diseases.

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OBITUARY

Prof. Avtar Singh Atwal

FOUNDER PRESIDENT

Indian Ecological Society

Prof. Avtar Singh Atwal was born on June 25, 1927 at village Khanewal, District Multan, now in Pakistan. He did his B.Sc. (Agriculture) from Punjab Agricultural College and Research Institute, Lyallpur (Pakistan) in 1947, where he obtained first position in the University and was awarded the Gold Medal. He completed his Ph.D. from the Waite Agricultural Research Institute, University of Adelaide, South Australia in 1954 under the Colombo Plan. He remained Post Doctorate Research Fellow of the National Research Council of Canada during 1955-57. It was during his doctoral research when he came into contact with eminent ecologists working and visiting the Section of Ecology and thus, he imbibed the spirit of ecological principles and practices which he later introduced in the academics of the Punjab Agricultural University, Ludhiana.

Prof. Atwal started his professional career as Lecturer in Entomology in 1947 and worked as Assistant Professor/Associate Professor till 1960. He was Entomologist to the Government of Punjab and State Locust Control Officer (1961-63), when he introduced successfully the aerial spraying for locust control. He was the first Professor and Head, Department of Zoology-Entomology of the newly formed Punjab Agricultural University (PAU), Ludhiana (1963-66). He worked as Dean, College of Agriculture (1966-73 and 1975-79) and Dean, Post Graduate Studies (1979-85), PAU, Ludhiana. In between, he was Advisor to Jammu & Kashmir Government and Vice-Chancellor (Designate), J & K Agricultural University (1973-75) and prepared the project for establishing the University. He worked as full time Member, Punjab State Planning Board (1986-89). Even when he worked on other positions, he maintained his interest in ecological approach to pest control and agricultural development for the first 20 years, and in the role of honey bees and other insects for the pollination of crops for the next 20 years. He has published 15 books, 150 research papers and 100 reviews and strategy papers on agricultural education, research and development.

Prof. Atwal has made outstanding contributions in the fields of agricultural research, education and development. He was the first scientist in India to successfully introduce the Italian honey bee, *Apis mellifera* Linnaeus in early sixties through a unique experiment, using the technique of interspecific queen introduction. *A. mellifera* colonies were raised by introducing the fertilized queens among the workers of *Apis cerana* Fabricius. Persistent efforts spread over a decade led to the successful establishment of *A. mellifera* in Punjab and the entire Indo-Gangetic plains where Honey Revolution has followed the Green Revolution. Prof. Atwal will be remembered as the Father of Modern Beekeeping in India as he opened new vistas of commercial beekeeping in the country. As one of the founder Deans of Punjab Agricultural University, Prof. Atwal played a pivotal role in introducing many innovative programmes and developing several new Departments. He was instrumental in revising and restructuring the PAU course curricula keeping in view the changing educational needs. For making education wholesome many new disciplines were started and trained faculty was recruited by making personal contacts from throughout India and even foreign countries. Some of the new disciples of Ecology, Forestry, Agrometeorology, Food Science and Technology, and Floriculture and Landscaping at PAU are the outcome of his visionary approach in planning. The College of Agriculture being the premier institute of PAU, played the most significant role in ushering Green Revolution in the state. It was during his tenure as Dean, when this college had won the Institution Award of the Federation of Indian Chambers of Commerce and Industry in 1977.

Prof. Atwal established the Indian Ecological Society in 1974 and was its founder President. The Indian Ecological Society is one of the oldest in this field and has been responsible for bringing the ecological perspective in the academic and applied spheres of life in India. He nurtured this society with complete devotion and organized several symposia and conferences.

The books written by Prof. A. S. Atwal would continue to shape up the destiny of students and teachers in many Asian countries. His monumental book "Agricultural Pests of South Asia and Their Management" is one of the most popular text books ever written on this subject; since its first publication in 1976, the book has been reprinted many times with eight revisions. Even after his retirement, he continued to publish for the benefit of students and farmers; his recent book "*Mellifera* Beekeeping and Pollination" has been acclaimed as a master piece giving details of behaviour of four species of honey bees and their role in crop pollination.

Prof. Atwal was a widely traveled person, visiting more than 35 countries in almost all the continents of the world. He has been a member of several national and international bodies associated with agricultural research and development. He has attended 20 World Congresses and 25 International Conferences related to various aspects of agriculture, ecology and environment.

Prof. Atwal expired on September 26, 2014 after a brief illness. The Indian Ecological Society deeply mourns his sad demise and prays for peace to the departed soul.

G S Dhaliwal
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